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Referential Coding Does Not Rely on Location Features: Evidence for a Nonspatial Joint Simon Effect

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The joint Simon effect (JSE) shows that the presence of another agent can change one's representation of one's task and/or action. According to the spatial response coding approach, this is because another person in one's peri-personal space automatically induces the spatial coding of one's own action, which in turn invites spatial stimulus-response priming. According to the referential coding approach, the presence of another person or event creates response conflict, which the actor is assumed to solve by emphasizing response features that discriminate between one's own response and that of the other. The 2 approaches often make the same predictions, but the spatial response coding approach considers spatial location as the only dimension that can drive response coding, whereas the referential coding approach allows for other dimensions as well. To compare these approaches, the authors ran 2 experiments to see whether a nonspatial JSE can be demonstrated. Participants responded to the geometrical shape of a central colored stimulus by pressing a left or right button, while wearing gloves of the same or different color as the stimuli. Participants performed the task individually, either by responding to either stimulus shapes (Experiment 1) or by responding to only 1 of the 2 shapes (Experiment 2), and in the presence of a coactor. Congruence between stimulus and glove color affected performance in the 2-choice and the joint tasks but not in the individual go/no-go task. This demonstration of a nonspatial JSE is inconsistent with the spatial response coding approach but supports the referential coding approach.

Keywords: joint Simon effect, referential coding, spatial response coding, dimensional overlap, compatibility effect

How does the presence of, or the collaboration with, another individual affect the way people represent their own tasks and actions? This has been the main question of numerous recent studies that investigated human action control in interactive contexts (Becchio, Sartori, & Castiello, 2010; Knoblich, Butterfill & Sebanz, 2011; Pacherie, 2012). To do so, researchers have taken established tasks and paradigms from cognitive psychology and turned them into joint tasks by requiring the concurrent or alternating action of two participants (Sebanz, Knoblich & Prinz, 2003; Welsh et al., 2005; Atmaca, Sebanz, Prinz, & Knoblich, 2008; Heed, Habets, Sebanz, & Knoblich, 2010; Milanese, Iani, & Rubichi, 2010; Atmaca, Sebanz, & Knoblich, 2011; Liepelt & Prinz, 2011; Böckler, Knoblich, & Sebanz, 2012; Liepelt, Stenzel, & Lappe, 2012; Pfister, Dolk, Prinz, & Kunde, 2014). Most of the available data come from the joint Simon task, developed by Sebanz et al. (2003), which is the joint version of the standard Simon task.

In the standard version of the Simon task (Simon & Small, 1969) participants perform spatially defined responses (e.g., left and right button presses) to a nonspatial stimulus attribute, such as color. The location of the stimulus varies randomly in such a way that it can spatially correspond or not correspond to the position of the required response. Typically, responses are faster and more accurate when they spatially correspond to the location in which the stimulus is presented—the so-called Simon effect (Simon & Small, 1969). The occurrence of such an effect suggests that even though stimulus position is neither relevant nor informative, it is nevertheless automatically processed to such a degree that it affects response selection (Kornblum, Hasbroucq, & Osman, 1990; De Jong, Liang, & Lauber, 1994; Kornblum & Lee, 1995). Ac-

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cording to the dimensional overlap model (Kornblum et al., 1990; Kornblum, 1994; Kornblum & Lee, 1995), the Simon effect results from a match/mismatch between the irrelevant (spatial) dimension of the stimulus and the relevant (spatial) dimension of the response. The presentation of a lateralized stimulus is assumed to automatically prime the spatially corresponding response, thus facilitating response selection when it is the correct one and inducing time-consuming response conflict when it is incorrect (Kornblum et al., 1990; De Jong, Liang, & Lauber, 1994; Hommel, Müsseler, Aschersleben & Prinz, 2001; see Hommel, 2011, for a review).

Recent findings showed that the Simon effect occurs in the joint version of the task as well—an observation that we will refer to as the joint Simon effect (JSE; Sebanz et al., 2003). In the joint version of the Simon task, the two response buttons are operated by two different individuals, sitting next to each other and responding each to only one of the two stimulus values. In other words, each participant performs a go/no-go task. Interestingly, turning the standard two-choice Simon task into a go/no-go task by having participants respond to only one of the two stimulus alternatives by pressing only one of the two keys eliminates the Simon effect (Hommel, 1996). And this makes theoretical sense: performing just one response does not require or suggest coding this response as left or right, so that the stimulus location code no longer matches or mismatches with the (no longer existing) response code. However, performing this go/no-go task side-by-side with another person makes the Simon effect reappear—the JSE (Sebanz et al., 2003). This suggests that the presence of a coactor changes one's representation of the task and/or one's action.

Several theoretical suggestions have been made as to why that might be the case. Originally, the occurrence of the JSE was taken to reflect the automatic corepresentation of other human beings (i.e., the other's actions and/or the task rules that govern them) through a dedicated social perception-action mechanism (Sebanz, Knoblich, & Prinz, 2005a; Sebanz, Bekkering, & Knoblich, 2006; Knoblich & Sebanz, 2006; Sebanz & Knoblich, 2009). However, recent studies have demonstrated that the JSE does not rely on the presence of another human but can also be induced by inanimate but dynamic (and, thus, attention-attracting) objects, such as a Japanese waving cat or a metronome (Dolk, Hommel, Prinz & Liepelt, 2013; see also Dolk et al., 2011). This does not support the assumption of a dedicated social mechanism but suggests that the effect can be induced by any dynamic event.

According to the spatial response coding account, this might be because a coactor (or the event in question) provides participants with a spatial reference frame that stimulates or forces them to code their own action spatially, that is, as left or right (Guagnano, Rusconi, & Umiltà, 2010; Dittrich, Rothe, & Klauer, 2012; Dittrich, Dolk, Rothe-Wulf, Klauer, & Prinz, 2013). This reintroduces a dimensional overlap between the task-irrelevant stimulus dimension (horizontal stimulus location) and the response dimension (horizontal response location), which in turn provides the necessary conditions for the Simon effect to occur (Kornblum et al., 1990). As predicted by the spatial response coding account, JSE-like effects are not observed when the spatial reference frame provided by the coactor is made less salient (i.e., when the coactor performs his or her part of the task further away from the participant's peri-personal space; Guagnano et al., 2010; but see Welsh et al., 2013a; see also Guagnano, Rusconi, & Umiltà, 2013, and Welsh et al., 2013b) or is missing (i.e., when the coactor acts in a different and spatially nonspecified room; Sellaro, Treccani, Rubichi & Cubelli, 2013; see also Welsh, Higgins, Ray, & Weeks, 2007.[1] Moreover, the JSE can be experimentally induced (vs. suppressed) by increasing (vs. decreasing) the salience of the shared spatial dimension of the stimuli and the responses, namely, by making different spatial stimulus and response codes (i.e., horizontal vs. vertical arrangements of stimuli, responses, and coacting participants) converge or not (Dittrich et al., 2012, 2013).

Even though these findings are encouraging, the spatial response coding account is unable to explain a whole number of observations. For instance, the size and probability of the JSE has been shown to depend on the agenthood and/or human-likeness of the coactor (Tsai & Brass, 2007; Müller et al., 2011a; Stenzel et al., 2012), the personal relationship (Hommel, Colzato, van den Wildenberg, 2009; see also Ruys & Aarts, 2010, and Iani, Anelli, Nicoletti, Arcuri & Rubichi, 2011) and the perceived similarity (Müller et al., 2011b) between actor and coactor, the actor's mood (Kuhbandner, Pekrun, & Maier, 2010), religious orientation (Colzato, Zech et al., 2012), self-construal (Colzato, de Bruijn, & Hommel, 2012), the experimentally induced style of thinking (Colzato, van den Wildenberg, & Hommel, 2013), and the agency underlying the alternative action event (Stenzel et al., 2014). It is difficult to see why all that would follow from automatically induced spatial-coding processes.

Because of these and other weaknesses of that approach, the referential coding account (Dolk et al., 2013, see also Dolk et al., 2011, 2014) has been suggested. According to this account, spatial response coding is not triggered by the mere presence of another individual in peri-personal space. Instead, actors are assumed to code their actions spatially to solve an action-discrimination problem (see Ansorge & Wühr, 2004, for a response-discrimination account of the Simon effect). According to the Theory of Event Coding (TEC; Hommel et al., 2001), the cognitive system represents self-produced actions and other perceived (social and nonsocial) events alike (through codes of their sensory consequences; Hommel et al., 2001; Hommel, 2009, 2011), which invites crosstalk between action representations and representations of other events (see also ideomotor theory; James, 1890; see Shin, Proctor, & Capaldi, 2010; Stock & Stock, 2004, for reviews). If so, the presence of other salient events, and the resulting cognitive representation thereof, can be assumed to induce response-selection conflict: the agent needs to decide whether a given stimulus would need to be followed by his or her own action or by the other event (see also Liepelt, Wenke, Fischer, & Prinz, 2011; Liepelt, Wenke, & Fischer, 2013). This discrimination problem can be reduced by emphasizing features that distinguish between the two alternative events (cf. intentional weighting; Hommel et al., 2001; see Memelink & Hommel, 2013, for a review), which in the standard joint Simon task is location. Hence, the referential coding approach shares the assumption of the spatial response coding account that spatial response coding is the crucial factor for the JSE to occur, but it develops a different scenario of why responses are

[1] It is worth mentioning that Tsai, Kuo, Hung, and Tzeng (2008) did observe a JSE when the actor and the coactor performed the joint Simon task in two different rooms. However, as underlined by Sellaro et al. (2013), the occurrence of the JSE in Tsai's et al. study is likely to reflect confounding spatial factors underlying their experimental procedure.

spatially coded. This scenario allows the referential coding approach to account for the findings that the spatial response coding approach cannot explain. For instance, if actor and coactor are similar or positively related, their representations become more similar and are thus more difficult to discriminate (e.g., Davis, Conklin, Smith, & Luce, 1996; Aron, Aron, Tudor, & Nelson, 1991). This should lead to more emphasis on features supporting discrimination, such as location, which in turn should produce a more pronounced JSE (Hommel et al., 2009). Consistently, the JSE is more pronounced when the perceived or the "real" similarity between the actor and the coactor is high (Müller et al., 2011a; Müller et al., 2011b; Stenzel et al., 2012; Stenzel et al., 2014) and when the two coacting participants are engaged in a positive (Hommel et al., 2009) and/or a cooperative relationship (Iani et al., 2011; see also Ruys & Aarts, 2010). Likewise, a cognitive state that favors information integration—as induced by good mood (Ashby, Isen & Turken, 1999), collectivistic religions (Colzato, Hommel, van den Wildenberg, & Hsieh, 2010), interpersonal orientation (Kühnen & Oyserman, 2002) and divergent thinking (Fischer & Hommel, 2012)—should counteract discrimination between actor and coactor, which in turn should increase the JSE, as the available evidence indeed shows (see Kuhbandner et al., 2010; Colzato, de Bruijn, & Hommel, 2012; Colzato, Zech et al., 2012; Colzato et al., 2013).

Although the referential coding approach is more comprehensive than the spatial response coding approach, the two approaches often make the same predictions for situations where they both apply. Importantly for the purpose of the current study, however, they differ with respect to the relevance of the spatial dimension: whereas the spatial response coding approach considers location to be the only dimension on which responses can be coded (at least as far as the JSE is concerned), the referential coding approach allows any perceptual dimension to serve as the basis of response discrimination. Accordingly, the referential coding approach predicts that it should be possible to create a nonspatial JSE, whereas the spatial response coding approach would not allow for that. We therefore designed two experiments with the aim to create a nonspatial JSE. In particular, we implemented three versions of the Simon task: a standard two-choice (solo) version, an individual go/no-go and a joint go/no-go task. In these versions, participants wore colored (red and/or green) gloves and were asked to discriminate the geometrical shape (circle vs. triangle) of a centrally presented stimulus by pressing one of two lateralized buttons marked with labels of the same color as the gloves they wore. Importantly, the target stimulus was randomly shown in red or green so that it did or did not match the color of the glove worn by the hand in charge of responding. At variance with the standard Simon task and its joint version, color (but not location) was the irrelevant stimulus dimension and the instruction defined the responses in terms of their colors but not in terms of their spatial location.

Depending on the task, participants were required either to wear both the red and the green glove and to respond to either stimulus shape (in the two-choice task; see Figure 1, Panel A), or to wear only one of the two gloves and to respond to only one of the two stimulus shapes (in both the individual go/no-go and the joint tasks; see Figure 1B and 1C). In the joint task, the actor performed the task next to a coactor wearing the glove of the alternative color and responding to the alternative stimulus shape (see Figure 1C).

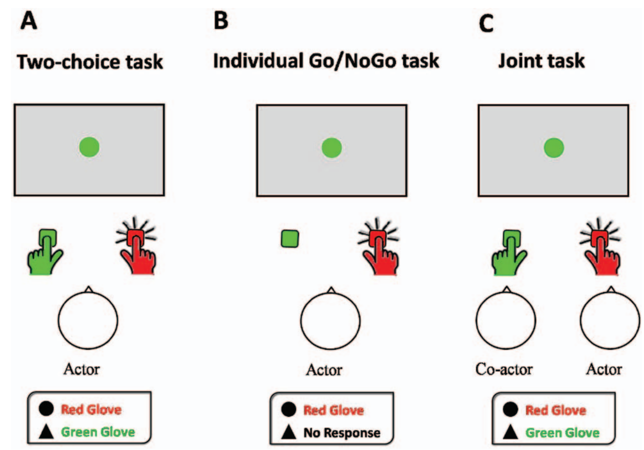

Figure 1. Schematic representation of the tasks used in Experiments 1 and 2. Throughout each task, the response buttons were marked with colored labels: green (light gray) and red (dark grey). Participants were instructed to respond to the geometrical shape (circle vs. triangle) of a centrally presented stimulus. Targets were randomly shown red (dark grey) and green (light grey). In the two-choice task (A), participants wore both the green (light grey) and the red (dark grey) gloves and had to respond to both stimulus shapes. In the individual go/no-go task (B), participants wore only one of the two gloves, either on the left or on the right hand, and were instructed to respond either to the circle or to the triangle. In the joint task (C), the task was distributed between two participants (actor and coactor), each wearing only one of the two gloves and responding to only one of the two stimulus shapes. For each task, the figure illustrates an example of an incongruent trial. See the online article for the color version of this figure.

Based on the dimensional overlap model (Kornblum et al., 1990; Kornblum & Lee, 1995), we expected to observe a nonspatial Simon effect in the two-choice task (which would amount to conceptual replications of Kornblum, 1994, and Hommel, 2004) but not in the individual go/no-go task. In the joint task, however, the expectation depended on the theoretical background. According to the response coding account, the presence of a close-by coactor automatically induces participants to code their response as "left" or "right" with reference to the coactor's position. As the stimuli did not vary in terms of location, this should not produce any compatibility effect, which would suggest that no JSE would be expected. In contrast, the referential coding account would predict that the presence of another response would induce a response-selection conflict, which the actor would solve by emphasizing features discriminating between his or her own action and that of the coactor. This may or may not apply to location (the increased coding of which our design could not diagnose anyway) but it should definitely apply to color. Accordingly, the referential coding account predicts a nonspatial, color-based JSE in the joint-action condition.

Method

Participants

Sixty-four students of the Leiden University participated in the experiment for partial fulfillment of course credit or a financial reward (€ 3), 32 in Experiment 1 (8 males; mean age: 21.1 years) and 32 in Experiment 2 (8 males; mean age: 21.3 years). Participants were recruited via an online recruiting system and came to the lab as unacquainted couples.[2] All participants were naïve regarding the purpose of the experiment and had a normal or correct-to normal vision. Written informed consent was obtained from all participants.

Apparatus, Stimuli, and Procedure

Participants were seated at a viewing distance of 60 cm from a 17-inch monitor screen. A small (0.5 × 0.5 cm) black cross presented in the center of a gray screen served as fixation point. In each trial, the target stimulus was either a circle (1.5 cm in diameter) or a (1.5 × 1.5 cm) triangle. The target stimulus was presented in the center of the screen and it randomly appeared in red or green color. Participants were required to respond as fast and accurate as possible to the geometrical shape of the target stimulus while ignoring its color. In the two-choice task, participants operated one response button in response to the circle and the other response button in response to the triangle. In both the individual go/no-go and the joint tasks, they only pressed one of the two buttons in response to either the circle or the triangle. Responses were executed by pressing the "q" or "p" button of a QWERTY keyboard with the left or right index finger, respectively. Throughout the tasks, both response buttons were marked with two colored labels, one in red and the other in green.

Importantly, participants were required to wear colored (red and green) gloves. In the two-choice task participants wore the green glove on one hand and the red glove on the other hand (Figure 1A). In both the individual go/no-go and the joint tasks, participants wore either the green or the red glove on one hand and no glove on the other (Figure 1B and 1C). In the joint task, participants were flanked by a coactor wearing a glove of the alternative color and responding to stimuli of the alternative shape. Participants sitting on the left wore the colored glove on the left hand, while participants sitting on the right wore the colored glove on the right hand (e.g., if the actor wore the red glove on the right hand, the coactor wore the green glove on the left hand; see Figure 1C). The colored glove-hand assignment and the stimulus-response mapping were counterbalanced according to a Latin square design.

In both experiments, participants performed two tasks. In Experiment 1, participants performed the two-choice task and the joint task, and in Experiment 2 they performed the individual go/no-go task and the joint task. In both experiments, the order of the two tasks was counterbalanced, with the colored glove-hand assignment and the stimulus-response mapping kept constant across the two tasks. A single experiment with a fully within-subjects design was avoided, given that (a) contrary to the classical Simon effect (Simon, Craft, & Webster, 1973), the JSE is not overly robust and, because of its small magnitude, quite sensitive to practice effects and (b) similar to the classical Simon effect, it is sensitive to transfer effects from one task to the other (Ansorge & Wühr, 2004; Milanese et al., 2010; Proctor & Vu, 2006).

In all tasks, each trial began with the presentation of the fixation cross for a random period between 1450 and 1950 ms. Then the target stimulus was shown until response, but not longer than 800 ms. If the response was correct, the trial was followed by a 300-ms blank interval. In case of an error (i.e., responses to the wrong shape, and/or with latencies exceeding 800 ms), a visual error feedback (the word *fout*, Dutch for "error") was presented in the center of the screen for 300 ms.

The two-choice task comprised of two blocks, whereas both the individual go/no-go and the joint tasks consisted of three blocks. Each block consisted of 60 trials, half with color glove-stimulus congruence and half with color glove-stimulus incongruence. All tasks were preceded by a practice block of 20 trials.

Statistical Analyses

In both experiments, correct mean reaction times (RTs) and percentage of errors (PEs) were submitted to separate analyses of variance with two within-subjects factors: task (joint vs. individual, either two-choice, in Experiment 1, or individual go/no-go, in Experiment 2) and color congruence (congruent vs. incongruent trials). Newman–Keuls post hoc analyses were performed to clarify mean differences in case of significant interactions. A significance level of $p < .05$ was adopted for all statistical tests. In addition, we calculated Bayesian probabilities associated with the occurrence of the null (H_0) and alternative (H_1) hypotheses, given the observed data (see Masson, 2011 and Wagenmakers, 2007). This method allows making inferences about both significant and nonsignificant effects by providing the exact probability of their occurrence, with values ranging from 0 (*i.e., no evidence*) to 1 (*i.e., very strong evidence*) (see Raftery, 1995 for a coarse classification).

Experiment 1

The aim of Experiment 1 was twofold: to verify the presence of a nonspatial Simon effect in the two-choice task and to assess whether a comparable effect (i.e., a nonspatial JSE) can occur in the joint task. To this end, participants were required to perform the two-choice task and the joint task in balanced order. As already mentioned, the dimensional overlap model (Kornblum et al., 1990; Kornblum, 1994) would predict a nonspatial Simon effect in the two-choice task. Indeed, a small (10 ms) but significant nonspatial Simon effect was observed in a recent study using a very similar paradigm in which, however, the target stimulus conveyed both a spatial and a nonspatial irrelevant information (i.e., targets were lateralized stimuli of different shapes randomly shown in two different colors and participants were to respond to the shape of the target while wearing colored gloves; Wühr & Biebl, 2009). Of particular interest, the presence or absence of a nonspatial JSE would be critical in providing evidence supporting the referential coding account (Dolk et al., 2013, see also Hommel et al., 2009, and Dolk et al., 2011) or the spatial response coding account (Guagnano et al., 2010; Dittrich et al., 2012, 2013), respectively.

Results and Discussion

Both RT and PE analyses showed a significant main effect of task: $F(1, 31) = 58.20$, $p < .001$, $\eta^2 = .65$ (RTs), $p(H_1|D) > .99$; $F(1, 31) = 22.60$, $p < .005$, $\eta^2 = .42$, $p(H_1|D) > .99$ (PEs). Responses were faster and more accurate in the joint (353 ms and 1.7%) than in the two-choice (393 ms and 4.6%) task. Moreover,

[2] Participants who did not show up were replaced by a confederate in the joint task. Participants were not aware that their partner was a confederate.

the main effect of color congruence was significant in both RTs—$F(1, 31) = 20.13$, $p < .001$, $\eta^2 = .39$, $p(H_1|D) > .99$—and PEs—$F(1, 31) = 12.29$, $p < .001$, $\eta^2 = .28$, $p(H_1|D) = .97$—, with participants being faster and more accurate in congruent (369 ms and 2.3%) than incongruent (377 ms and 4.0%) trials. Importantly, in both analyses the interaction between task and color congruence was not significant (Fs ≤ 1.47, ps $\geq .23$, $p(H_0|D) = .85$ and $p(H_0|D) = .73$ for RT and PE analyses, respectively). Regardless of the task, RTs were faster and more accurate in congruent trials than incongruent trials: 389 versus 397 ms (Cohen's $d = .49$) and 3.5% versus 5.7% ($d = .57$), in the two-choice task; 349 versus 357 ms ($d = .59$) and 1.1% versus 2.3% ($d = .36$), in joint task; see also Figure 2.

The results of this experiment, besides confirming the occurrence of a nonspatial Simon effect in the two-choice task, demonstrate that a comparable effect can be observed in the joint task as well. Indeed, small (8 ms) but statistically significant effects were observed in both tasks, an observation that provides evidence against the spatial response coding account (Guagnano et al., 2010; Dittrich et al., 2012, 2013). According to this account, participants should have merely coded their response as "left" or "right" with reference to the coactor's position, which should have eliminated the basis for the congruency effect in the joint task. As solid congruency effects were obtained, the results support the referential coding account (Dolk et al., 2013; see also Hommel et al., 2009, and Dolk et al., 2011) instead and suggest that referential response coding can be based on any salient (spatial or nonspatial) feature.

Experiment 2

Experiment 2 aimed at providing convergent evidence by directly comparing participants' performance in two identical tasks that differed only in the presence (vs. absence) of the coactor—the typical procedure employed in this kind of studies. To this end, participants performed the same go/no-go task in a joint condition (together with a coactor) and individually. As in Experiment 1, the order of the two tasks was counterbalanced.

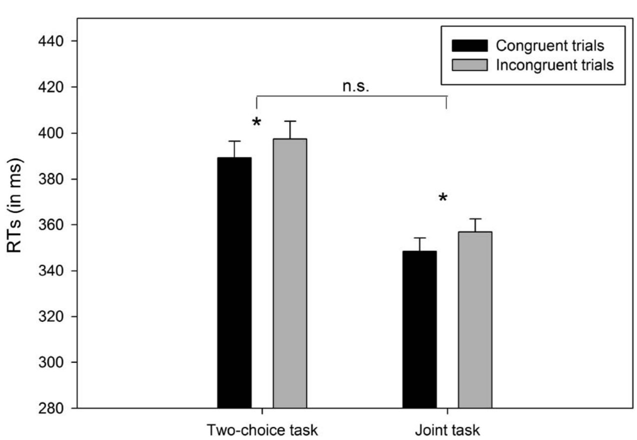

Figure 2. Mean reaction times (RTs) for congruent (black) and incongruent (light gray) trials for the two-choice task (left) and the joint task (right). Vertical capped lines atop bars indicate standard error of the mean. Asterisk indicates significant (* $p < .05$) difference between congruent and incongruent trials.

First of all we expected to replicate the finding observed in Experiment 1: a nonspatial JSE should be observed in the joint task. In contrast, in the individual go/no-go task no effect should emerge (Hommel, 1996). It is worth noting, however, that during the individual go/no-go task the alternative response button was marked by a colored label, whose color was the alternate of that of the glove worn by the participant (see overview of the method and Figure 1B). Participants might code their response as "red" or "green" relative to the color of the alternative response button, thus showing the effect in the individual go/no-go task as well. Therefore, should we observe the effect in the joint but not in the individual go/no-go task, such a dissociation would provide rather strong evidence for the assumption that only salient (attention-attracting) *events* can act as a reference for response coding (cf., Dolk et al., 2013, 2014).

Results and Discussion

The RT analysis revealed a main effect of color congruence, $F(1, 31) = 7.07$, $p = .01$, $\eta^2 = .19$; $p(H_1|D) = .83$. Participants were faster in congruent (341 ms) than in incongruent (346 ms) trials. Most importantly, the interaction between task and color congruence was significant, $F(1, 31) = 6{,}53$, $p = .015$, $\eta^2 = .17$, $p(H_1|D) = .79$. Post hoc analyses showed that the difference between congruent and incongruent trials was significant in the joint task (338 vs. 347 ms, $p < .001$, $d = .74$) but not in the individual go/no-go task (344 vs. 345 ms, $p = .44$, $d = .10$; see also Figure 3). The main effect of task was not significant, $F < 1$, $p = .68$, $p(H_0|D) = .84$. The analysis of PEs (0.9%) revealed no main effect or interaction (Fs ≤ 2.3, ps $\geq .14$, $p_s(H_0|D) \geq .64$).

As expected, we observed a small (9 ms) but significant nonspatial JSE in the joint task but not in the individual go/no-go task (1 ms). These results confirm and extend the findings of Experiment 1: Besides replicating the occurrence of the nonspatial JSE in a different group of participants they confirm that only salient events afford the referential coding of the participant's response (Dolk et al., 2013).

General Discussion

The present study compared the two similar, but nonidentical accounts of the JSE (Sebanz et al., 2003): the spatial response coding account (Guagnano et al., 2010; Dittrich et al., 2012, 2013) and the referential coding account (Dolk et al., 2013; see also Dolk et al., 2011). As mentioned in the introduction, the two accounts share the idea that what is critical for the standard JSE to occur is the spatial coding of the actor's response relative to the coactor's position, which would produce the necessary dimensional overlap between the stimulus and the response sets to induce the Simon effect (Kornblum et al., 1990). However, the two accounts differ with respect to what is thought to lead participants to code their response spatially. Following the spatial response coding account, participants cannot help coding their response in spatial terms because the task setting itself, namely, the spatial relationship between the two coacting participants, would automatically induce such a kind of coding. In contrast, according to the referential coding account, participants code their response spatially only if, and because, the "left" and "right" response feature can be easily used to differentiate one's own action from the coactor's action—a

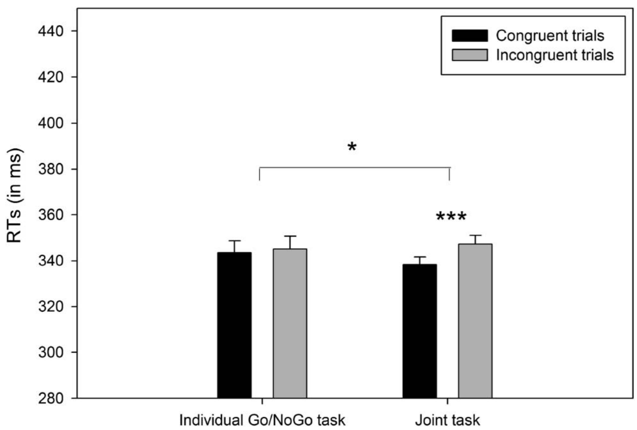

Figure 3. Mean reaction times (RTs) for congruent (black) and incongruent (light gray) trials for the individual go/no-go task (left) and the joint task (right). Vertical capped lines atop bars indicate standard error of the mean. Asterisk indicates significant (* $p < .05$, *** $p < .001$) difference between the two tasks and between congruent and incongruent trials.

problem that necessarily arises whenever alternative and conflicting action events are concurrently represented (Dolk et al., 2013; Hommel et al., 2001; see also Dolk, Liepelt, Villringer, Prinz, & Ragert, 2012; Liepelt et al., 2012). An important implication of this reasoning is that participants may also use other, nonspatial features to discriminate their own response from others—if such features are available and salient. If so, it should be possible to create a nonspatial JSE.

We tested this prediction by having two participants sitting side-by-side (as in a standard joint Simon task) and wearing colored gloves. They performed a task in which, unlike the joint Simon task, the target stimulus did not convey any spatial information, which prevented a spatial Simon effect to occur. Instead of location, the irrelevant stimulus dimension was color, which could overlap or not overlap with the color associated with either the actor's own or the coactor's response. According to the spatial response coding approach, only location codes should account, which would not lead one to expect any impact of response color and the overlap between stimulus and response color. In contrast, the referential coding approach would predict that participants might not, or not only code their response in terms of spatial location but (also) in terms of its salient color features. If so, a nonspatial JSE should emerge based on the overlap between stimulus and response color.

The results of two experiments provided converging evidence questioning the privileged role of location features in inducing referential response coding (cf. spatial response coding account; Guagnano et al., 2010; Dittrich et al., 2012, 2013). Indeed, in both experiments a nonspatial JSE was observed, which implies that participants coded their responses on the basis of the color dimension, although the arrangement of the two participants allowed for spatially based coding. Consistent with previous studies addressing compatibility effects in joint contexts (e.g., the JSE; Sebanz et al., 2003; the joint SNARC effect; Atmaca et al., 2008; the joint flanker effect; Atmaca et al., 2011), the congruency effect observed in the joint task was identical in size to the one obtained in the individual two-choice task, where participants operated both responses themselves (in Experiment 1). In addition, the absence of the effect in the individual go/no-go task in Experiment 2 suggests that referential response coding is restricted to conditions in which alternative salient events are available.

Thus, the present results favor the referential coding account over the spatial response coding account. As we have already pointed out in the introduction, the referential coding account relies on the assumptions that referential response coding is necessary to discriminate alternative action events and that sufficiently salient events can afford the referential coding of the response. These assumptions can be better understood on the background of the theoretical framework they were inspired by, namely, the TEC (Hommel et al., 2001; Hommel, 2009). Broadly speaking, TEC posits that, given the assumed bidirectional link between perception and action (the core assumption of the ideomotor theory; James, 1890; Stock & Stock, 2004; Shin, Proctor & Capaldi, 2010), the cognitive system does not differentiate between self-produced actions and other perceived (social and nonsocial) events. In this view, a responding coactor (or any other salient object) is simply another event.

A logical implication of TEC is that the more features are shared by different events (i.e., the more they are similar and the more their representations overlap), the more they can be related to, compared with, or confused with each other. Therefore, the implementation of alternative action-like events introduces a discrimination problem comparable to the one that arises when a specific target needs to be selected among distractors. Solving this problem necessitates first of all to determine a selection criterion, that is, to select the object feature (e.g., position, shape, or color) that will guide such a discrimination (e.g., Wolfe, 1994). It is reasonable to assume that the selection criterion relies on features that make a given object salient relative to other candidates. Similarly, preparing for a given action requires an agent to direct attention to (i.e., to increase the weight of) those perceptual dimensions (e.g., color, shape, position, etc.) that are relevant to accomplish the task (cf. intentional weighting principle; Hommel et al., 2001; Memelink & Hommel, 2013). Because perceived events (stimuli) and action events (responses) are represented using the same feature codes (cf. Hommel et al., 2001), "making a particular dimension relevant for perceptual discriminations should automatically induce task relevance of the same dimension in action discriminations" (Memelink & Hommel, 2013, p. 253). This explains how, depending on the dimension that is made salient by a given task, referential response coding can rely on different spatial and nonspatial dimensions. In typical Simon and joint Simon tasks, the location features are the most salient ones, and it may well be that location features have a privileged status in attention and action control (Treisman & Gelade, 1980; Miller, Carlson, & Hill, 2011). Accordingly, referential coding is induced with regard to location features whenever they are available and sufficiently salient. However, as demonstrated in the present study, responses can also be coded with respect to other features, such as color, provided that they are salient and serve to discriminate between alternative responses (Hommel, 2004). Given that self-generated and other-generated actions are coded in terms of their sensory consequences (Hommel et al., 2001; Hommel, 2011, 2009), it is not surprising that perceived action effects (e.g., the illumination of a left/right light; Kiernan et al., 2012; see also Pfister et al., 2014) can be used for referential coding as well.

As we discussed in the introduction, the referential coding account can easily accommodate for findings that the spatial response coding account cannot explain. The core idea of the referential coding account is that the JSE is produced whenever an alternative action event is made available, regardless of its source (self vs. other) and its nature (social vs. nonsocial). The representation of an alternative action event creates a similar conflict that arises when representing more than one's own possible actions. This is why the occurrence of the JSE is not restricted to the presence of human coactors but is likewise induced by nonsocial salient (i.e., attention-attracting) events (Dolk et al., 2011, 2013). Needless to say that for a response conflict to come into play the representation of the alternative action event needs to be sufficiently active. Alternative action events that share features along the same dimension as those events that are used for internal action selection, are most active and hence produce the strongest action discrimination problem. Consistent with that, manipulations that de-emphasize the existence of an alternative action event (e.g., by instructing the two coacting participants to react simultaneously to the same stimulus alternative; Lam & Chua, 2010), are likely to reduce the likelihood of the JSE. Conversely, manipulations that emphasize the existence of the alternative action event (e.g., by instructing the two coacting participants to react to different features of the imperative stimulus; Sebanz et al., 2005a) are likely to increase the size of the JSE.

Furthermore, the referential coding account can explain why the size of the JSE is sensitive to factors that are related to the perceived or real interpersonal similarity (Tsai & Brass, 2007; Müller et al., 2011a; Müller et al., 2011b; Stenzel et al., 2012) and to the quality (Hommel et al., 2009) and to the nature (cooperative vs. competitive) of the interpersonal relationship (Ruys & Aarts, 2010; Iani et al., 2011). As previously mentioned, the more features are shared between self and other (perceptual and/or conceptual features), the more their representations overlap (Dolk et al., 2013, 2014; see also Hommel et al., 2009). Following Dolk et al. (2013, 2014) this makes response discrimination more difficult and leads participants to attend the most salient response-discrimination feature. Increasing the weight of the response-discrimination feature increases the feature overlap with the stimuli, which increases the size of the compatibility effect. The same reasoning can account for the findings showing that the size of the JSE can be either increased or decreased by inducing a specific temporary cognitive control state, able to favor or to counteract, respectively, self-other overlap (Kuhbandner et al., 2010; Colzato, de Bruijn, & Hommel, 2012; Colzato, Zech et al., 2012; Colzato et al., 2013). These latter findings are particularly relevant as they suggest that the JSE can be controlled by the same mechanisms and according to the same principles that allow one to control other cognitive control operations.

As already mentioned in the introduction, the pivotal study of Sebanz et al. (2003) ignited some controversy about the nature and the mechanisms underlying the JSE. Three main theoretical interpretations have been advanced (for a recent review, see Dolk et al., 2014): the action/task corepresentation account (Sebanz & Knoblich, 2009; Sebanz et al., 2006; Knoblich & Sebanz, 2006; Sebanz et al., 2005a), the spatial response coding account (Dittrich et al., 2012, 2013; Guagnano et al., 2010), and the referential coding account (Dolk et al., 2013, 2014; see also Hommel et al., 2009, and Dolk et al., 2011). Although previous studies compared the action/task corepresentation account with the spatial response coding account (Guagnano et al., 2010; Dittrich et al., 2012, 2013; Sellaro et al., 2013) and/or with the referential coding account (Dolk et al., 2011, 2013), the present study sought to pit the spatial response coding approach against the referential coding account—two theoretical interpretations that often have been mixed up and were considered to be interchangeable. Accordingly, we implemented a task suitable to this purpose. That being said, it is worth pointing out that our results are in principle also consistent with the action/task corepresentation account, as one might ascribe the occurrence of a nonspatial JSE to the automatic mental representation of the coactor's action/task (Sebanz et al., 2005a; Sebanz et al., 2006; Knoblich & Sebanz, 2006; Sebanz & Knoblich, 2009). However, even though our findings do not provide any evidence against the action/task corepresentation account—an issue beyond the aim of the present study—we do consider the referential coding approach to be more suitable (and even more parsimonious) to account for the present findings and for the JSE in general. The reason is twofold. First, there is still a lack of understanding of the precise mechanism that, according to the action/task corepresentation account, gives rise to the JSE. Indeed, the explanation provided by the action/task corepresentation account is limited to the assumption that action/task corepresentation is an automatic and dedicated social process (Sebanz et al., 2006; Sebanz & Knoblich, 2009).[3] Second, the action/task corepresentation account is unable to explain a number of observations that, instead, are easy to reconcile with the flexibility of the referential coding account. For instance, it does not explain why high-functioning autistic patients, who typically have deficits in processing social information, show a JSE as well (Sebanz et al., 2005b; for a more detailed discussion, see Humphreys & Bedford, 2011), why nonsocial events are able to produce JSE-like effects (Dolk et al., 2011, 2013), and why the JSE is sensitive to the temporary cognitive control state (Colzato et al., 2013). In any case, however, as our study was not designed to differentiate the referential coding from the action/task corepresentation account, the present findings are obviously not conclusive on that issue.

To conclude, the present results show that the JSE is not a specifically spatial phenomenon, and that it is not automatically induced by the spatial coding of the actor's action relative to the coactor's position. In contrast, our results suggest that JSE-like effects can be elicited by different action event features, such as

[3] As argued elsewhere (for an extensive discussion, see Dolk et al., 2014), the action/task corepresentation account differs critically from the referential coding account. According to the action/task corepresentation account (Sebanz et al., 2005a; Sebanz et al., 2006; Knoblich & Sebanz, 2006; Sebanz & Knoblich, 2009) people mentally represent (unintentionally and quasi-automatically) other people's tasks, actions, as well as the goals and the intentions that govern them, and these representations become part of one's own task representation. Crucially, the action/task corepresentation account assumes that these (quasi-)automatic representations are formed because processing information about other people involves a dedicated social action-perception mechanism. Conversely, the referential coding account (Dolk et al., 2013, 2014; see also Hommel et al., 2009, and Dolk et al., 2011) claims that people represent the other person (or any other salient object) as an alternative action event—a reference they have to differentiate from, without necessarily requiring any other feature of the other person's action (e.g., intentions, goals) to be represented. Importantly, according to this account, universal information processing mechanisms are sufficient to explain the effect and its modulations.

the color, provided that these features are salient enough to afford the referential coding of the actor's action, necessary for enabling a proper discrimination between alternative concurrently activated action events (Dolk et al., 2013, 2014). However, one might argue that, in our design, space may still play a role, as what is really critical for perceiving two objects (or two persons) as separated is the fact that they occupy different spatial locations. Thus, future studies should extend our findings to rule out such a possibility, by using techniques, like virtual reality, that are able to disrupt self-other space boundaries. Furthermore, it would be interesting for future research to test more directly TEC assumptions (and, specifically, the intentional weighting mechanism) and its application to joint contexts by turning into joint task paradigms, like visual search tasks, that have provided the strongest evidence in favor of this approach.

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