# Whose turn is it anyway? The moderating role of response-execution certainty on the joint Simon effect

April Karlinsky,[1]

Melanie Y. Lam,[2]

Romeo Chua,[1]

[*]Nicola J. Hodges[1]

Karlinsky, A., Lam, M. Y., Chua, R., & Hodges, N. J. (2019). Whose turn is it anyway? The moderating role of response-execution certainty on the joint Simon effect. *Psychological research*, *83*(5), 833-841.
https://link.springer.com/article/10.1007/s00426-017-0901-7

https://doi.org/10.1007/s00426-017-0901-7

[1]School of Kinesiology, University of British Columbia

210-6081 University Boulevard

Vancouver, BC

V6T 1Z1, Canada

[2]Department of Human Kinetics, St. Francis Xavier University

[*]Corresponding Author:

Nicola J. Hodges

E-mail: nicola.hodges@ubc.ca

Telephone: 604-822-5895

Fax: 604-822-6842

Acknowledgements: This research was supported by a Discovery grant from the Natural Sciences and Engineering Research Council of Canada (NSERC) award to NJH. We thank the Editor and two anonymous reviewers for their thought provoking comments and suggestions.

Abstract

When a two-choice “Simon task” is distributed between two people, performance in the shared go/no-go task resembles performance in the whole task alone. This finding has been described as the joint Simon effect (JSE). Unlike the individual go/no-go task, not only is the typical joint Simon task shared with another person, but the imperative stimuli dictate whose turn it is to respond. Therefore, in the current study, we asked whether removing the agent discrimination component of the joint Simon task influences co-representation. Participants performed the typical joint Simon task, which was compared to two turn-taking versions of the task. For these turn-taking tasks, pairs predictably alternated turns on consecutive trials, with their respective imperative stimulus presented either on 100% of their turns (fully-predictable group) or on 83% of their turns (response-uncertainty group, 17% no-go catch trials). The JSE was absent in the fully-predictable, turn-taking task, but emerged similarly under response-uncertainty and typical joint Simon task conditions, where there is both turn and response-execution-related uncertainty. These results demonstrate that conflict related to agent discrimination is likely not a critical factor driving the JSE, whereas conflict surrounding the need to execute a response (and hence the degree of preparation) appears fundamental to co-representation.

# Whose turn is it anyway? The moderating role of response-execution certainty on the joint Simon effect

Social interactions pervade daily life, from passing a cup of coffee to a co-worker, to lifting furniture with a friend, to passing a ball to a teammate. While the specific demands of each interaction will vary from one occasion to the next, joint actions are thought to be generally underpinned by action representations, action monitoring, and action prediction processes (Vesper et al. 2010). Although joint actions often fulfill joint goals, it is also the case that two people will be working in pairs towards independent goals, for example, practicing drills in a team sport's setting. In this study, we evaluated potential factors influencing performance in a joint task that does not require collaboration, but has been shown to promote task/action co-representation (i.e., the joint Simon task, Sebanz et al. 2003). In particular, we asked whether it is turn (agent) discrimination or response uncertainty, potentially related to the level of movement preparation, which encourages co-representation. Specifically, we investigated whether being able to preemptively prepare a response shields against co-representation and a corollary joint Simon effect.

In recent years, researchers have explored the nature of action representations and how they might influence performance in an individual versus joint context. A valuable task towards this end has been a spatial correspondence task (the Simon task), which can be performed under both individual (e.g., Simon 1969) and joint conditions (e.g., Sebanz et al. 2003). In the standard Simon task, an individual responds to lateralized stimuli with a left or right key press, based on an arbitrary stimulus feature (e.g., colour, shape, tone pitch). Although irrelevant to the task, stimulus location modulates responses, such that they are faster and more accurate when the stimulus appears on the same rather than the opposite side as the correct response location (corresponding

and non-corresponding trials, respectively). This pattern of results is commonly referred to as a correspondence or Simon effect and has been related to conflict at the response selection stage (for review, see Lu and Proctor 1995).

In the joint version of the Simon paradigm, the stimulus-response (S-R) mappings are distributed amongst two people, such that each partner performs a go/no-go protocol independent from, yet complementary to their partner's task (joint go/no-go task, JGNG). In this situation, there are no longer any response selection requirements (as each co-actor is assigned a single S-R mapping), yet a correspondence effect is still shown (henceforth referred to as a joint Simon effect, JSE; Sebanz et al. 2003). This is despite the lack of such an effect when participants perform the same go/no-go protocol alone (Sebanz et al. 2003). Sebanz and colleagues (2003) interpreted the JSE to reflect a dedicated social mechanism, wherein individuals automatically represent a co-actor's task even though there is no advantage in doing so (and typically some costs). Importantly, this joint situation also has turn (agent) uncertainty that is lacking in the individual situation, and it may be that this uncertainty in whose turn it is acts rather like a response selection decision contributing to the spatial conflict and the presence of a JSE.

Researchers have recently suggested that it is an action-reference that critically underpins the effect, as opposed to a socially-driven phenomenon (e.g., Dolk et al. 2011, 2013). As such, any sufficiently salient action event – related to a biological agent or not (e.g., a ticking metronome, Dolk et al. 2013) – can contribute to the response conflict that is thought to elicit the JSE (Dolk et al. 2014). However, this does not explain why social variables have been shown to influence the emergence of the effect (for review, see Dolk et al. 2014). Dolk and colleagues (2014) addressed this limitation by integrating social and non-social interpretations of the JSE in their referential coding account, in which they highlight how greater similarity across action-event representations

can lead to a greater emphasis on their discriminating features (e.g., location). This referential coding explanation can account for the occurrence of the JSE within non-social settings as well as for the more pronounced JSEs when there is increased self-other integration. In this latter case, the discriminating spatial feature is likely more heavily weighted, as with friendly partnerships (e.g., Hommel et al. 2009), in-group interactions (e.g., Iani et al. 2011; McClung et al. 2013; Müller et al. 2011), and cooperative contexts (e.g., Iani et al. 2011, 2014).

Given the typical need to differentiate between self- and other-generated action events within social contexts, some researchers have explored how the relationship between stimuli and responding agents affects joint action, rather than the relationship between stimuli and the responses themselves (e.g., Milanese et al. 2011; Philipp and Prinz 2010). In one study, participants performed a novel social compatibility task under individual and joint go/no-go conditions, responding to imperative stimuli presented simultaneously with socially-relevant but task-irrelevant stimuli (i.e., coloured diamonds superimposed centrally on the actor's face, a neutral face, or the co-actor's face, Philipp and Prinz 2010, Experiment 2). A face-agent compatibility effect arose only during the joint task, that is, faster responses when the actor's face was shown and slower responses when the neutral or co-actor's face was shown. This suggests that in this social setting, the actor's face acted as a signal that it was their turn, while a different face signaled another's turn (Philipp and Prinz 2010). These findings indicate a role for discriminating the responding agent towards joint task performance (the actor identification account, Philipp and Prinz 2010). Wenke and colleagues (2011) similarly posited in their actor co-representation account that "participants might not always co-represent *what* their partner is supposed to do, but instead co-represent *that* another agent is responsible for part of the task, and *when* it is his turn" (p. 147, emphasis in original).

In line with this actor co-representation account, Baess and Prinz (2015) used electroencephalography (EEG) to investigate the processes related to participants' discrimination between their own versus their co-actor's turn in a go/no-go reaction time task (different to the joint Simon task). They showed that engaging in a joint task significantly modulated neural correlates of early visual processing. Specifically, the N1 response (i.e., the first negative potential related to stimulus perception) was lower in the joint go/no-go condition compared to the individual go/no-go condition, providing evidence that the social setting influenced early processes of stimulus identification and differentiation. Based on these N1 response data, the authors speculated that task sharing might, at its core, be a case of self/other discrimination (for neuroimaging support of agent identification activities within joint tasks, see Sebanz et al. 2007). However, in order to isolate the processes of agent identification and selection, agent-identifying stimuli (stimulus colour) were presented in advance of the response selection and go signals, such that there was no uncertainty in whose turn it was to respond on any given trial (Baess and Prinz 2015). This form of agent precuing starkly contrasts with the typical joint Simon task (e.g., Sebanz et al. 2003), wherein the imperative stimulus serves simultaneously as agent identifier and go signal (such that uncertainty as to whose turn it is and whether to respond are inextricably tied). This raises the question of how the form of task-sharing, and the sources of uncertainty therein (e.g., when and if a co-actor must act) impact co-representation. Given that in the joint Simon task, there is technically no uncertainty surrounding co-actors' response selection (as they are assigned a single response alternative), we henceforth refer to the uncertainty surrounding how to respond as response-execution uncertainty.

In the typical joint Simon paradigm, a task-sharing scenario not unlike doubles' tennis is created, where co-actors are responsible for approximately 50% of the randomly interspersed

responses. Alternative task distributions and response assignments have been considered and these have been shown to moderate or eliminate the JSE. For example, Lam and Chua (2010) assigned partners to the same S-R pairing (i.e., responding on the same trial), and as predicted, co-representation was no longer demonstrated in the absence of complementary response alternatives. When both co-actors were randomly presented (distinct) targets on 80% of the trials ('double responses') and individual targets on the remaining 20% ('single responses', 10%/co-actor), the JSE was exhibited across both trial types (Guagnano et al. 2010, see also Welsh et al. 2013). Although the large proportion of double response trials was designed to promote participants' independent task performance (Guagnano et al. 2010), the inclusion of co-actor single response trials (i.e., no-go trials) added an element of uncertainty as to whose turn it was to respond, potentially contributing to the JSE in both double and single response conditions. Indeed, it has been shown that action preparation differs significantly under conditions of complete versus incomplete response-execution certainty (e.g., Carlsen et al. 2004, 2008; Maslovat et al. 2012). When there is complete motor response certainty, a movement can be fully prepared in advance of the go signal (e.g., Carlsen et al. 2004; Maslovat et al. 2012) and hence may be less susceptible to bottom-up influences of a co-actor's (irrelevant) actions (see Carlsen et al. 2008 for evidence that motor responses are not fully prepared in advance of the go signal in individual go/no-go tasks). To our knowledge, the roles of turn and response-execution (un)certainty have yet to be addressed in the context of the joint Simon task, despite interest in the impact of self-other discrimination within task sharing (e.g., Baess and Prinz 2015; Wenke et al. 2011).

In the current study, we asked whether turn uncertainty (i.e., agent discrimination) and/or response-execution uncertainty are critical components of the joint Simon task, contributing to co-representation. We provided advance knowledge of whose turn it was to respond, through a simple

task instruction manipulation. Such a manipulation is analogous to changing the JGNG protocol from task sharing akin to doubles' tennis (50% turn certainty before stimulus onset) to that of doubles' table tennis (100% turn certainty before stimulus onset, as the rules dictate response alternation between partners). All participants completed the typical, unpredictable JGNG task (e.g., Sebanz et al. 2003) on Day 1 of the study, before performing one of two novel turn-taking versions of the task on Day 2. All partners predictably alternated turns on consecutive trials, with their respective imperative stimulus presented either on 100% of their turns (fully-predictable condition) or on 83% of their turns (response-uncertainty condition, 17% no-go catch trials). We included the latter condition to evaluate whether certainty about responding mitigates JSEs. As with the JGNG task, this group would not be able to fully prepare their response in advance of the go-signal and as such, may continue to be susceptible to co-representation effects (and response conflict).

In summary, the typical JGNG condition involved a situation of both turn and response-execution uncertainty, the fully-predictable condition involved both turn and response-execution certainty, and finally the response-uncertainty condition involved a situation of turn-certainty and response-execution uncertainty. Note that a fourth combination involving turn uncertainty and response-execution certainty was not possible. In such a condition, the turn uncertainty would lead to a situation in which one could not fully prepare to execute the response in advance, thereby reintroducing response-execution uncertainty. The fully-predictable and response-uncertainty conditions, and the comparison with the JGNG condition, enabled us to evaluate the potential influences of turn (agent) and response-execution certainty on co-representation, which to date have been confounded (given that in the typical JGNG task, one's turn and one's need to respond are inseparable). We hypothesized that the JSE would manifest itself under typical JGNG task

conditions. If conflict related to agent identification is a critical component of the JSE (e.g., Wenke et al. 2011), then the JSE should be eliminated in both turn-taking groups, where the need to determine whether it is "my turn" or the "other's turn" to respond is resolved (although without a condition of response and turn uncertainty, which is not possible in the current design, agent identification effects cannot be fully isolated). However, to extend the table tennis analogy, even though the matter of whose *turn* it is to respond can be preemptively determined, an alternative source of uncertainty is whether one *should* respond (e.g., execute or withhold a return depending on if the ball is in or out, respectively). If conflict surrounding the need to respond is fundamental to co-representation, then the JSE should be eliminated in the fully-predictable group, yet persist in the response-uncertainty group.

## Methods

### Participants and Groups

Forty-four individuals with normal or corrected-to-normal vision participated in the experiment (*M* age = 24.7 yr, *SD* = 4.2 yr; 3 left-handed).[1] Participants completed the 2-day experiment in pairs, with a self-selected friend. Pairs were assigned in alternation to either the fully-predictable group (*n* = 22, 15 females) or the response-uncertainty group (*n* = 22, 12 females). The study was conducted in accordance with the ethical guidelines set out by the University and all participants provided informed written consent.

### Materials and Apparatus

A computer was used to control stimulus presentation and record participants' responses via a customized E-Prime 2.0 program (Psychology Software Tools, Inc., Sharpsburg, PA). The stimuli were presented on a monitor (ASUS HDMI 23 in.) set in the middle of a desk. Two chairs were

placed side-by-side facing the monitor, with a response key fixed on the desk in front of each of the chairs.

**Procedures**

The experiment was conducted over two consecutive days, with one task performed each day with the same partner (a self-selected friend). Pairs of friends were used to optimize the likelihood of providing a friendly, positive performance environment and eliciting a JSE (see Hommel et al. 2009). Instructions were presented verbally by the experimenter and visually on the monitor at the beginning of each task.

All pairs completed the typical JGNG task on Day 1 of testing. For this task, each member of the pair was instructed to respond to one of the two ring colours as quickly and as accurately as possible, with the ring colours presented randomly. Participants were randomly assigned to the left or right seat, with chair position determining participants' response hand (i.e., left chair-left hand or right chair-right hand). Participants used their index finger to respond while resting their inactive hand on their lap. Pairs completed 8 practice trials followed by four blocks of 80 experimental trials, with short breaks between each block. Each trial started with the presentation of a white fixation cross in the centre of a black background. The imperative stimulus replaced the fixation cross after 500 ms and depicted a human hand with the index finger extended and pointing to either the left or to the right. A blue or yellow ring appeared on the pointing finger and each participant was instructed to respond to one of the colours by pressing their designated response key. The stimuli were always presented centrally, with the ring appearing in the same location. The stimuli remained on screen until a response was made, for a maximum of 1500 ms. The inter-trial interval was 1500 ms.

On Day 2 of testing (~24 hours later), participants continued to sit in the same seat, use the same response hand, and respond to the same target colour as previously. Pairs performed a novel turn-taking version of the JGNG task depending on group. Both the fully-predictable and response-uncertainty turn-taking tasks required partners to continuously alternate turns responding to the imperative stimulus, as quickly and as accurately as possible, with the yellow ring presented on trial 1 of each block (followed by blue... yellow… blue… etc.). The response-uncertainty group also experienced randomly interspersed catch trials, where no ring appeared on the image of the hand during their turn. The catch trial served as the participant's turn, such that the subsequent trial still belonged to the partner (e.g., yellow… blue… catch… blue…). Like the typical JGNG task, these turn-taking conditions for the 2 groups consisted of 8 practice trials followed by four blocks of 80 experimental trials. However, due to the inclusion of catch trials, the response-uncertainty condition included 2 additional practice trials (2 catch trials) and 16 additional catch trials/block (distributed equally between partners) resulting in four blocks of 96 trials.

## Results

### Response Errors

Trials on which the wrong key was pressed or no response was registered were considered errors and excluded from further analysis. The data from 1.3% of trials were removed in the typical JGNG condition, from 0.1% of trials in the fully-predictable condition, and from 0.1% of trials in the response-uncertainty condition (excluding catch trials). Within the response-uncertainty condition, although participants were reminded not to respond on catch trials, after practice and any subsequent erroneous responses, two participants (1 pair) responded on 50.0% and 40.6% of their catch trials and hence were excluded from the data set for non-compliance with task

instructions. Of the remaining 10 pairs, participants erroneously responded on 12.2% of the catch trials.[2]

The remaining data were sorted by trial type (based on stimulus colour and stimulus-response correspondence). Trials were coded as corresponding when the image of the hand pointed to the same side as the correct response and as non-corresponding when the hand pointed to the opposite side of the correct response. Trials in which response times (RTs) were shorter than 100 ms, longer than 1000 ms, and two standard deviations above or below the participant's mean for that trial type were considered errors and excluded from further analysis. Four participants were excluded from analysis due to RTs during the fully-predictable condition that were considered anticipatory (based on RT criteria of <100 ms) on 24-59.4% of their trials. For the remaining participants, data were excluded from 4.1% of trials in the typical JGNG condition, from 6.0% of trials in the fully-predictable condition, and from 3.7% of trials in the response-uncertainty condition.

**Response Time**

Alpha was set at $p < .05$ for all statistical tests. Partial eta squared values ($\eta_\rho^2$) are reported as measures of effect size, and power values ($1 - \beta$) are given for non-statistically significant effects where $F > 1$. Significant effects and interactions were followed up with Tukey HSD procedures.

Mean RTs are presented in Figure 1 (for $n = 18$ and $n = 20$ for the fully-predictable and response-uncertainty groups, respectively). We first compared each group's performance on the typical and turn-taking versions of the JGNG task in a 2 Group (fully-predictable, response-uncertainty) x 2 Task (typical, turn-taking) x 2 Correspondence (corresponding, non-corresponding) repeated measures ANOVA. There were main effects of group, task, and correspondence. The fully-predictable group responded faster ($M = 307$ ms, $SD = 68$ ms), than the

response-uncertainty group ($M$ = 344 ms, $SD$ = 54 ms), $F(1, 36) = 8.27$, $p = .007$, $\eta_\rho^2 = .19$. RTs were also shorter in the turn-taking ($M$ = 306 ms, $SD$ = 70 ms) compared to the typical JGNG task ($M$ = 347 ms, $SD$ = 49 ms), $F(1, 36) = 21.89$, $p < .001$, $\eta_\rho^2 = .38$, and on corresponding ($M$ = 319 ms, $SD$ = 61 ms) compared to non-corresponding trials ($M$ = 333 ms, $SD$ = 66 ms), $F(1, 36) = 61.19$, $p < .001$, $\eta_\rho^2 = .63$. The analysis also revealed significant interactions between Group and Task, $F(1, 36) = 38.19$, $p < .001$, $\eta_\rho^2 = .52$, and Task and Correspondence, $F(1, 36) = 14.98$, $p < .001$, $\eta_\rho^2 = .29$. Note that the two-way interaction between Group and Correspondence was not significant, $F(1, 36) = 1.08$, $p = .31$, $1 - \beta = .17$, indicating that the groups did not fundamentally differ in their susceptibility to the correspondence effect. Importantly, any 2-way interactions were superseded by a significant three-way interaction, $F(1, 36) = 9.68$, $p = .004$, $\eta_\rho^2 = .21$. To interpret the three-way interaction, we conducted separate ANOVAs on the fully-predictable and response-uncertainty groups separately, as detailed below.

**Evidence of co-representation in situations of response-execution uncertainty.** For the response-uncertainty group, RTs were shorter on corresponding ($M$ = 336 ms, $SD$ = 53 ms) than non-corresponding trials ($M$ = 352 ms, $SD$ = 55 ms), $F(1, 19) = 37.04$, $p < .001$, $\eta_\rho^2 = .66$, but importantly this effect did not depend on task ($F < 1$), nor did task mediate RTs in general, $F(1, 19) = 1.29$, $p = .27$, $1 - \beta = .19$ (see Figure 1).

**Evidence response-execution certainty mitigates co-representation.** For the fully-predictable group, there were main effects of both task and correspondence, such that RTs were shorter in the turn-taking task ($M$ = 256 ms, $SD$ = 42 ms) than in the typical JGNG task ($M$ = 357 ms, $SD$ = 48 ms), $F(1, 17) = 51.74$, $p < .001$, $\eta_\rho^2 = .75$, as well as on corresponding trials ($M$ = 300 ms, $SD$ = 64 ms) than on non-corresponding trials ($M$ = 313 ms, $SD$ = 72 ms), $F(1, 17) = 25.21$, $p < .001$, $\eta_\rho^2 = .60$. Critically, there was a significant interaction, such that RTs were only shorter on

corresponding trials compared to non-corresponding trials (i.e., a JSE) within the typical JGNG task (corresponding: $M$ = 346 ms, $SD$ = 48 ms; non-corresponding: $M$ = 368 ms, $SD$ = 47 ms) and not within the fully-predictable task (corresponding: $M$ = 255 ms, $SD$ = 40 ms; non-corresponding: $M$ = 257 ms, $SD$ = 44 ms), $F(1, 17) = 19.03$, $p < .001$, $\eta_p^2 = .53$ (see Figure 1).

While there was clearly no overall JSE in the fully-predictable condition, it is feasible that the effect might have manifested initially and diminished over time (e.g., as participants habituated to the task). To address this possibility, additional analyses of task and correspondence were performed for each group, including experimental block as a repeated measures factor. There were no block-related effects or interactions for either group ($F$s < 1), indicating that the effects reported above were stable across the experiment.

**Moderately correlated JSEs under typical JGNG and response-uncertainty condition.** The presence of a JSE under the response-uncertainty, turn-taking condition appears to demonstrate that co-representation occurs even when conflict surrounding agent identification is resolved, so long as there is uncertainty about the need to execute a response (*cf.* fully-predictable condition). However, it is possible that the response-uncertainty correspondence effect reflects a different process to that noted in typical conditions, perhaps due to an intrapersonal conflict to execute or withhold a response, regardless of the co-actor (although unlikely, given the typical lack of correspondence effect within individual go/no-go tasks, e.g., Sebanz et al. 2003). To explore this question, we ran Pearson's correlations between the JSE (i.e., difference between non-corresponding and corresponding trials) under typical JGNG and turn-taking conditions. As illustrated in Figure 2a, there was a moderately-sized, positive correlation between the individuals' JSE under typical JGNG and response-uncertainty conditions, $r(20) = .44$, $p = .053$. However, it was clear that this correlation was being driven down by one individual outlier, who showed a 27

ms JSE in the typical JGNG condition but a negative (-11 ms) JSE in the response-uncertainty condition. When this individual was not included in the analysis the correlation increased to $r(19) = .61$ and was now statistically significant ($p = .006$). There was a small, but not significant correlation between the typical JGNG and fully-predictable JSEs, $r(18) = .15$, $p = .55$ (Figure 2b).

## Discussion

We sought to disentangle the potential roles of uncertainty in co-representation JSEs, by studying the effects of both turn-certainty (i.e., agent discrimination) and certainty regarding the need to respond (i.e., response-execution certainty). These two sources of conflict have previously been confounded in joint Simon tasks, wherein imperative stimuli have simultaneously signalled the responding agent and action requirements of both co-actors (i.e., to execute or withhold a response; see also Baess and Prinz 2015). By designing two novel turn-taking conditions, we were able to compare agent discrimination-related conflict (the need to determine whether it is "my turn" or the "other's turn") from response-execution-related conflict (the need to determine whether to "go" or "not-to-go"), within the context of the joint Simon paradigm. We reasoned that if conflict related to self/other discrimination mediates the JSE (as per the actor co-representation account, Wenke et al. 2011; see also Philipp and Prinz 2010), then the effect should be attenuated in both the fully-predictable and response-uncertainty turn-taking conditions, where the responding agent is predetermined. However, if conflict surrounding whether or not to execute a response contributes to the JSE, then the effect should persist in the response-uncertainty (and typical JGNG) condition.

As expected, there was a significant JSE within the typical JGNG task, where there is uncertainty as to which co-actor's imperative stimulus will appear and consequently who will have to execute a response. In contrast, the absence of the JSE within the fully-predictable condition of the turn-taking task offers supportive evidence that co-representation is suppressed when there is

no uncertainty surrounding co-actors' responsibilities (i.e., what to do and when). Moreover, analyses using block as a factor indicated that this suppression was immediate and stable. Importantly, the JSE was eliminated even when the setting was otherwise designed to promote co-representation, including an active co-actor (e.g., Sebanz et al. 2003), responding to different stimulus-response alternatives (see Lam and Chua 2010), and a positive interpersonal relationship (e.g., Hommel et al. 2009).

The observation that the RTs within the fully-predictable, turn-taking condition were significantly shorter than within the typical JGNG (and response-uncertainty) condition is not surprising, given the simple RT nature of the former task. Unique to simple RT tasks is the ability to prepare a response in advance of the imperative stimulus (e.g., Carlsen et al. 2004; Maslovat et al. 2012). During the fully-predictable, turn-taking task, individuals always knew their course of action (as their predetermined, single S-R assignment was always presented on their turn) and hence could prepare their response in advance of detecting the stimulus. For individuals in this task, stimulus onset simply served as a cue to act. Thus, even if individuals had formed a representation of the co-actor's action alternative, it is likely that this advance preparation served to shield them against any bottom-up influence from the irrelevant spatial dimension of the stimulus, and hence, a correspondence effect.

In contrast, in the response-uncertainty condition, participants cannot fully prepare their response in advance as they might have to keep from acting (no-go catch trials). Indeed, there is evidence that in go/no-go tasks, individuals wait until they detect the imperative stimulus to complete motor programming (see Carlsen et al. 2008). That is, response uncertainty (even in the case where uncertainty is based on whether to execute or withhold a pre-selected response) allows for alternate responses to potentially conflict with, and hinder the completion of information-

processing operations required to execute the pre-selected response. In the case of the JSE, the stimulus's irrelevant spatial dimension can activate a representation of the co-actor's action alternative and thus produce a spatial correspondence conflict and corollary JSE. Empirical support that even minimal uncertainty surrounding the upcoming need to respond is conducive to co-representation is also provided by Guagnano et al. (2010) and Welsh et al. (2013), who observed JSEs using only 10% (compared to our 17%) no-go trials.

The presence of the JSE within the response-uncertainty turn-taking condition suggests that co-representation, at least as indexed by the JSE, is not driven by agent-related uncertainty, which was resolved by the predictable turn-taking protocol. This finding runs counter to the actor co-representation account (Wenke et al. 2011), which posits the need to discriminate between oneself and a co-actor as the source of co-representation effects (see also Dolk et al. 2014 for additional arguments against the actor co-representation account). Instead, even when individuals know it is their turn, uncertainty surrounding whether to execute a response (and consequently incomplete movement preparation) renders them susceptible to co-actor-related interference. Such interference and eventual conflict resolution likely occurs as described by the referential coding account (Dolk et al., 2013, 2014). The response conflict presumably arises because of the concurrent activation of the action alternatives, which need to be discriminated between to select the appropriate action representation. The spatial location of the alternative responses provides a clear discriminating feature, such that action representations are likely given spatial codes ("left" vs. "right"). These response location codes can then interact with the spatial coding of the stimuli, bringing about the stimulus-response correspondence effect (Dolk et al., 2013, 2014).

There was a moderately sized, positive correlation between the JSE in both the typical and response-uncertainty conditions, which is suggestive of similar mechanisms underpinning these

joint effects (although the correlation was only significant once we removed 1 outlier). This correlation across conditions was small and non-significant for the fully-predictable group, which is not surprising given that we did not see significant JSEs. The differences across turn-taking conditions with respect to the JSE also underscores the fact that the presence of a JSE was not just a result of prior priming due to the typical JGNG task always being performed first, otherwise the correlations would be similar for both groups. Rather, response-execution-related uncertainty appears to be a key feature of the JSE, presumably so long as both action alternatives are represented (e.g., Lam and Chua 2010) and/or there is some form of salient spatial reference (e.g., Dolk et al. 2013). These conditions are important, considering the typical lack of correspondence effect in individual go/no-go settings, which have 'turn' certainty and response-execution uncertainty (e.g., Sebanz et al. 2003, Experiment 1). The current turn-taking or similar precuing protocols could additionally be applied to help isolate the sources and stages of interference across various task-sharing activities, including the joint flanker (e.g., Atmaca et al. 2011; Dittrich et al. 2016; Dolk et al. 2014), the joint SNARC (e.g., Atmaca et al. 2008), the joint Navon (e.g., Böckler et al. 2012; Böckler and Sebanz 2012), and joint memory-based tasks (e.g., Elekes et al. 2016; Eskenazi et al. 2013).

The correlation between participants' JSEs for both the typical JGNG and response-uncertainty condition, supports the idea that the mechanism underpinning these effects are the same. However, evidence of JSEs in both these conditions, coupled with the correlation between the two only gives indirect evidence that both effects are being driven by similar mechanisms. It may be that the future inclusion of neurophysiological measurement will help to elucidate the processes underlying co-representation in different joint action contexts (for instance, ones that vary with respect to response predictability and associated degree of preparation). Indeed, Wenke

and colleagues (2011, Experiment 3) showed no evidence of task co-representation, as indexed by (the lack of) lateralized readiness potentials (LRPs) during a co-actor's turn when participants knew whose turn it was to respond before the go signal. In contrast, LRPs were exhibited during a co-actor's turn when the responding agent was unknown before the go signal (Tsai et al. 2006). It is perhaps unnecessary to engage in the same processes of (other-) action monitoring, simulation, and prediction when agents' responsibilities are predetermined and can be prepared in advance.

## Compliance with Ethical Standards

**Funding**: This study was funded by a Discovery grant from the Natural Sciences and Engineering Research Council of Canada awarded to Hodges (RGPIN-2016-04269).

**Conflict of Interest**: The authors declare that they have no conflict of interest.

**Ethical approval**: "All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards."

**Informed consent**: "Informed consent was obtained from all individual participants included in the study."

# References

Atmaca, S., Sebanz, N., & Knoblich, G. (2011). The joint flanker effect: Sharing tasks with real and imagined co-actors. *Experimental Brain Research, 211,* 371-385.

Atmaca, S., Sebanz, N., Prinz, W., & Knoblich, G. (2008). Action co-representation: The joint SNARC effect. *Social Neuroscience, 3*(3-4), 410-420.

Baess, P., & Prinz, W. (2015). My partner is also on my mind: Social context modulates the N1 response. *Experimental Brain Research, 233*(1), 105-113.

Böckler, A., Knoblich, G., & Sebanz, N. (2012). Effects of a coactor's focus of attention on task performance. *Journal of Experimental Psychology: Human Perception and Performance, 38*(6), 1404-1405.

Böckler, A., & Sebanz, N. (2012). A co-actor's focus of attention affects stimulus processing and task performance: An ERP study. *Social Neuroscience, 7*(6), 565-577.

Carlsen, A. N., Chua, R., Dakin, C. J., Sanderson, D. J., Inglis, J. T., & Franks, I. M. (2008). Startle reveals an absence of advance motor programming in a Go/No-go task. *Neuroscience Letters, 434,* 61-65.

Carlsen, A. N., Chua, R., Inglis, J. T., Sanderson, D. J., & Franks, I. M. (2004). Can prepared responses be stored subcortically? *Experimental Brain Research, 159*(3), 301-309.

Dittrich, K., Bossert, M.-L., Rothe-Wulf, A., & Klauer, K. C. (2016). The joint flanker effect and the joint Simon effect: On the comparability of processes underlying joint compatibility effects. *The Quarterly Journal of Experimental Psychology, 70*(9), 1808-1823.

Dolk, T., Hommel, B., Colzato, L. S., Schütz-Bosbach, S., Prinz, W., & Liepelt, R. (2014). The joint Simon effect: A review and theoretical integration, *Frontiers in Psychology, 5,* 1-10.

Dolk, T., Hommel, B., Colzato, L. S., Schütz-Bosbach, S., Prinz, W., & Liepelt, R. (2011). How "social" is the social Simon effect? *Frontiers in Psychology, 2*, 1-9.

Dolk, T., Hommel, B., Prinz, W., & Liepelt, R. (2013). The (not so) social Simon effect: A referential coding account. *Journal of Experimental Psychology: Human Perception and Performance, 39*(5), 1248-1260.

Dolk, T., Hommel, B., Prinz, W., & Liepelt, R. (2014). The joint flanker effect: Less social than previously thought. *Psychonomic Bulletin & Review, 21*(5), 1224-1230.

Elekes, F., Bródy, G., Halász, E., & Király, I. (2016). Enhanced encoding of the co-actor's target stimuli during a shared non-motor task. *The Quarterly Journal of Experimental Psychology, 69*(12), 2376-2389.

Eskenazi, T., Doerrfeld, A., Logan, G. D., Knoblich, G., & Sebanz, N. (2013). Your words are my words: Effects of acting together on encoding. *The Quarterly Journal of Experimental Psychology, 66*(5), 1026-1034.

Guagnano, D., Rusconi, E., & Umiltà, C. A. (2010). Sharing a task or sharing space? On the effect of the confederate in action coding in a detection task. *Cognition, 114*(3), 348-355.

Hommel, B., Colzato, L. S., & van den Wildenberg, W. P. M. (2009). How social are task representations? *Psychological Science, 20*(7), 794-798.

Iani, C., Anelli, F., Nicoletti, R., Arcuri, L., & Rubichi, S. (2011). The role of group membership on the modulation of joint action. *Experimental Brain Research, 211*(3-4), 439-445.

Iani, C., Anelli, F., Nicoletti, R., & Rubichi, S. (2014). The carry-over effect of competition in task-sharing: Evidence from the joint Simon task. *PLoS ONE, 9*(6), 1-8.

Lam, M. Y., & Chua, R. (2010). Influence of stimulus-response assignment on the joint-action correspondence effect. *Psychological Research, 74*(5), 476-480.

Lu, C.-H., & Proctor, R. W. (1995). The influence of irrelevant location information on performance: A review of the Simon and spatial Stroop effects. *Psychonomic Bulletin & Review, 2*(2), 174-207.

Maslovat, D., Carlsen, A. N., & Franks, I. M. (2012). Subcortical motor circuit excitability during simple and choice reaction time. *Behavioral Neuroscience, 126*(3), 499-503.

McClung, J. S., Jentzsch, I., & Reicher, S. D. (2013). Group membership affects spontaneous mental representation: Failure to represent the out-group in a joint action task. *PLoS ONE, 8*(11), 1-9.

Milanese, N., Iani, C., Sebanz, N., & Rubichi, S. (2011). Contextual determinants of the social-transfer-of-learning effect. *Experimental Brain Research, 211*(3-4), 415-422.

Müller, B. C. N., Kühn, S., van Baaren, R. B., Dotsch, R., Brass, M., & Dijksterhuis, A. (2011). Perspective taking eliminates differences in co-representation of out-group members' actions. *Experimental Brain Research, 211*(3-4), 423-428.

Philipp, A. M., & Prinz, W. (2010). Evidence for a role of the responding agent in the joint compatibility effect. *The Quarterly Journal of Experimental Psychology, 63*(11), 2159-2171.

Sebanz, N., Knoblich, G., & Prinz, W. (2003). Representing others' actions: Just like one's own? *Cognition, 88,* B11-B21.

Sebanz, N., Rebbechi, D., Knoblich, G., Prinz, W., & Frith, C. (2007). Is it really my turn? An event-related fMRI study of task sharing. *Social Neuroscience, 2*(2), 81-95.

Simon, J. R. (1969). Reactions towards the source of stimulation. *Journal of Experimental Psychology, 81*(1), 174-176.

Vesper, C., Butterfill, S., Knoblich, G., & Sebanz, N. (2010). A minimal architecture for joint action. *Neural Networks, 23*(8-9), 998-1003.

Welsh, T. N., Kiernan, D., Neyedli, H. F., Ray, M., Pratt, J., Potruff, A., & Weeks, D. J. (2013). Joint Simon effects in extrapersonal space. *Journal of Motor Behavior, 45*(1), 1-5.

Wenke, D., Atmaca, S., Holländer, A., Liepelt, R., Baess, P., & Prinz, W. (2011). What is shared in joint action? Issues of co-representation, response conflict, and agent identification. *Review of Philosophy and Psychology, 2*(2), 147-172.

## Footnotes

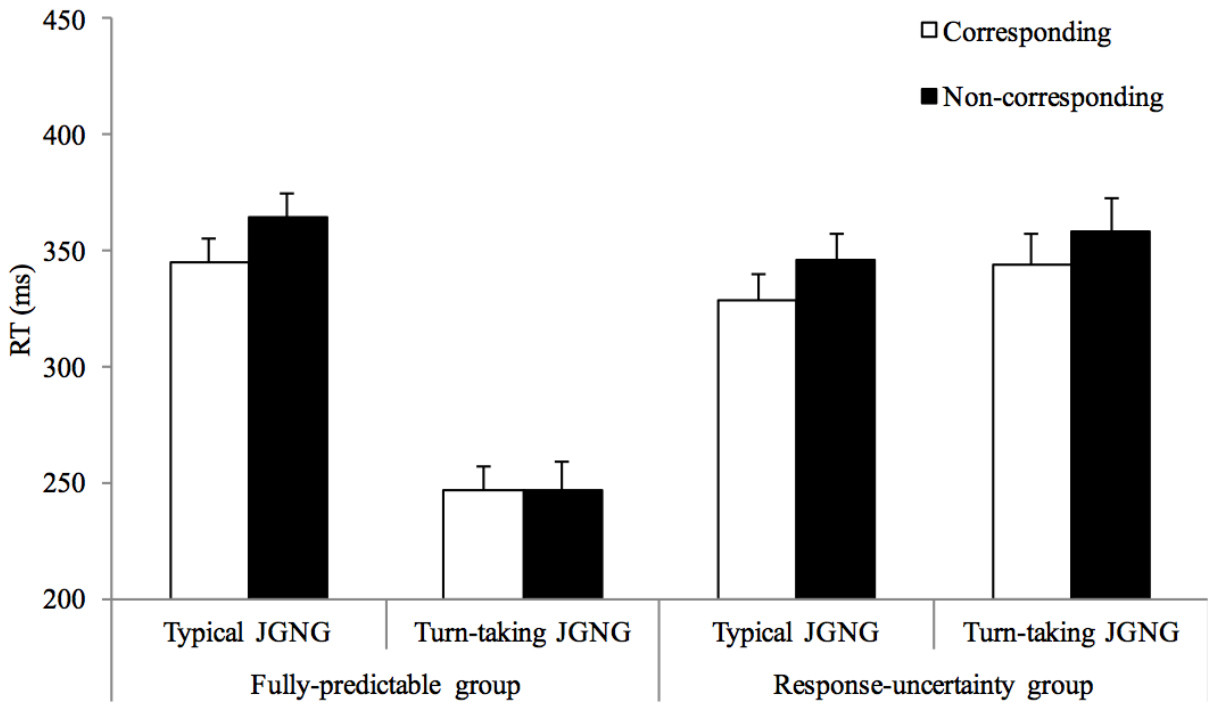
[1] All three left-handed participants were female. One responded with her dominant left hand while the other two responded with their right hand.

[2] The erroneous responses to catch trials were distributed across the experiment, with 26 responses in Block 1 (34.2% of errors), 14 responses in Block 2 (18.0% of errors), 21 responses in Block 3 (26.9% of errors), and 17 responses in Block 4 (21.8% of errors).

## Figure captions

**Fig. 1.** Mean RTs (error bars = 1 SEM) on corresponding and non-corresponding trials, under typical and turn-taking joint go/no-go (JGNG) task conditions, for the fully-predictable and response-uncertainty groups.

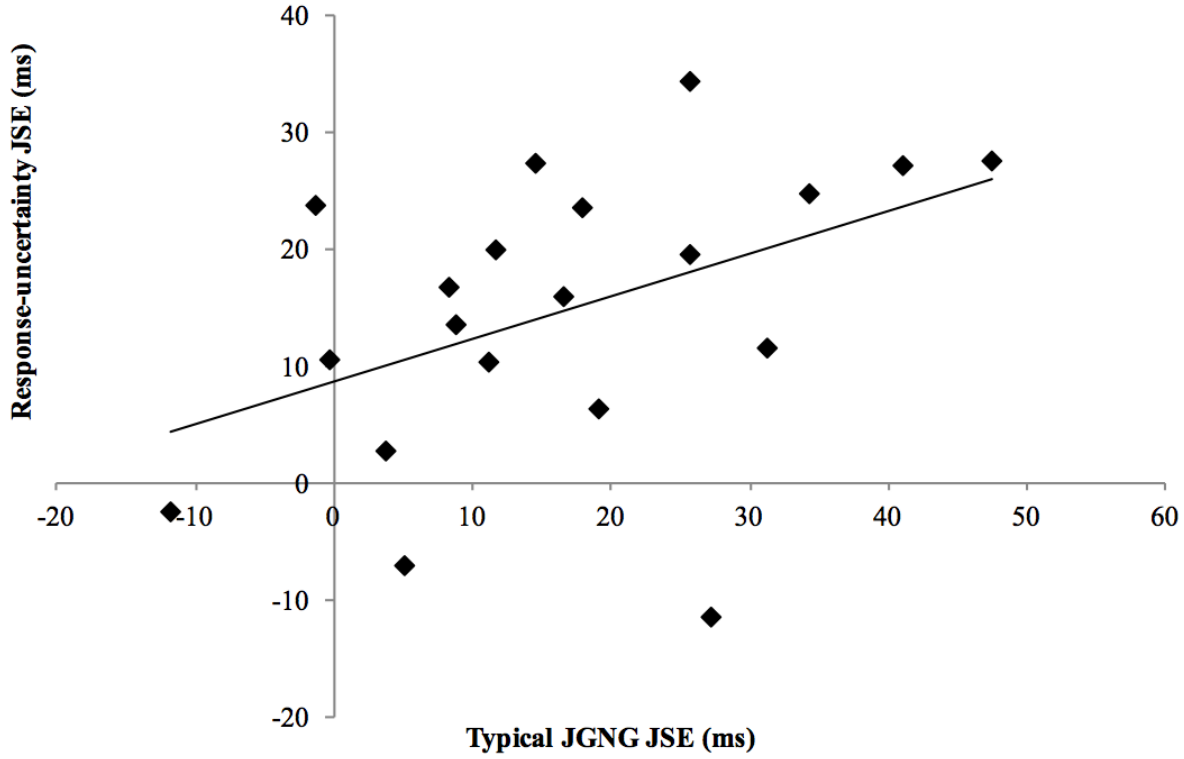
**Fig. 2.** Scatter plots showing individuals' mean joint Simon effect (JSE) in the typical joint go/no-go (JGNG) task as a function of A) mean JSE in the response-uncertainty turn-taking task and B) mean JSE in the fully-predictable turn-taking task.


450
400
350
300
250
200
RT (ms)
Corresponding
Non-corresponding
Typical JGNG
Turn-taking JGNG
Typical JGNG
Turn-taking JGNG
Fully-predictable group
Response-uncertainty group

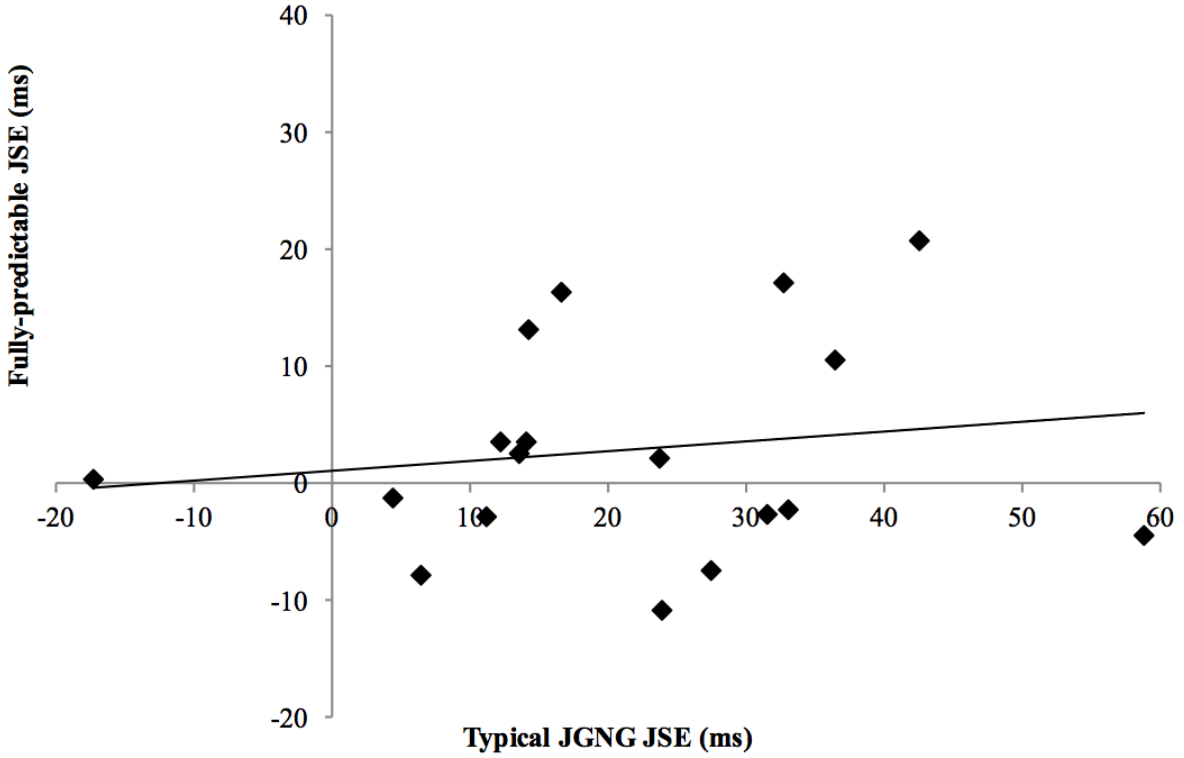
1

2

A)


Response-uncertainty JSE (ms)
40
30
20
10
0
-10
-20
-20
-10
0
10
20
30
40
50
60
Typical JGNG JSE (ms)

B)


Fully-predictable JSE (ms)
40
30
20
10
0
-10
-20
-20
-10
0
10
20
30
40
50
60
Typical JGNG JSE (ms)