Title: Joint task representations

Authors:

Affiliations:

Corresponding author:

# Abstract

Philosophers have been interested in distinguishing cases of joint action from cases of individual action by examining the content of the representations required to successfully carry out joint action. This is usually spelled out in terms of the propositional attitudes that can be ascribed to those engaged in the actions (e.g., see Bratman, 1993; Searle, 1990). An alternative approach, enabled by recent advances in the empirical study of joint action, is to examine joint action from the perspective of the task and motor representations that are formed when two people act together.

One often used method of examining the task and motor representations involved in joint performance has been to compare individual and joint performance of the Simon Task (Sebanz et al., 2003). This task requires an individual to perform half of a stimulus‐response compatibility task either alone or as part of a dyad. The results show that compatibility effects that are usually only observed when people perform both halves of the task alone are also observed when a dyad performs the task together. However, the interpretations of the data produced by the Joint Simon Task have been disputed and at least three alternative explanations for these effects have been proposed. The task co‐representation account suggests that individuals represent not only the specifics of their own task but also the specifics of their co‐actor’s task. The actor co‐representation account suggests that individuals merely represent the fact that another agent is responsible for half the joint task without representing the specifics of the other agent’s sub‐goals (Wenke et al., 2011). And, finally, the spatial coding account argues that rather than individuals forming a joint task representation during the Joint Simon task, the effects can be explained by the presence of another individual altering the way in which individuals represent their own responses in their individual task representation (e.g., see Dolk et al., 2011; Guagnano et al., 2010).

We present evidence from the joint task literature—including the joint Simon task and the joint Navon task (Böckler et al., 2012)—to show that all three mechanisms may be in play when people perform tasks with other people. However, rather than representing alternative explanations for a single effect, the accounts outlined above instead represent distinct ways in which people can perform a task together. Each of the mechanisms that underlie the different ways of task sharing are examined in turn. Furthermore, we examine the functional consequences of each mechanism, and the prior (task) conditions required to implement each mechanism.

Finally, we argue that the approach presented here not only elucidates the mechanisms that underlie joint action, but may also provide a principled means for differentiating joint actions from seemingly similar actions that are not joint actions.

# Introduction

The primary aim of the current paper is to address the question of how people include others in their planning. Philosophers have written extensively about the role that planning plays in coordinating actions within individuals—for example, coordinating present and future activities—and for coordinating actions between one agent and another (e.g., see Bratman, 1999). Most talk of planning refers to the (often) conscious deliberative process that shapes our actions. In this sense, to plan is to decide on a course of action and to consider the means by which to bring about a desired goal. These plans are often partial, and not every step is laid out in advance. For example, we can plan to go to the cinema tomorrow, but this plan need not entail my plan to write it down in my diary nor will it entail my plan of how I will move my fingers when proceeding to make the pen scratches in my diary that will later serve as my reminder.

However, there is another sense in which planning is used. This sense is often found in the psychological literature, and in particular the literature relating to control in the motor system (e.g., Wolpert, 1997). To highlight the distinction consider the case of planning to pick up a cup. I might plan to pick up a cup in the same sense that I plan to go to the cinema next week, but when I begin to reach out to grab the cup a lower level plan takes over the control of my action. This lower level plan determines the particulars of how my hand will move through space—the trajectory it will take, its velocity, the joint angles, and the adjustments made by my fingers as my hand approaches the target. This type of plan is not the result of conscious deliberation; it is not open to rational reflection; and it operates on time scales on the order of hundreds of milliseconds rather than minutes, days, or even years like higher level plans. However, lower level plans share with higher level plans their hierarchical structure ordered from means to ends and their functional role in shaping action, and thus are properly considered plans. While philosophers have often dealt with joint action using a higher level notion of planning, we attempt to provide an account of how agents include others in their plans that takes seriously the notion of planning at this lower level.

# Representations in joint tasks

When multiple agents are engaged in a joint task at least three things can be specified in the joint task plan. First, it is possible to specify what actions are required to satisfy the task requirements. In joint tasks this can be specified by means of an *action co-representation.*  Second, it is possibly to specify the task rules in terms of what actions are required in response to particular environmental features. This can be specified by means of a *task co-representation.*  Finally, the agent responsible for responding to particular parts of the task can be specified. This can be done through *actor co-representation*. Each of these is addressed in turn below.

In a joint task, responses might be required from both an agent and a co-actor. *Action co-representation* involves the agent not only forming a representation of what actions they might be required to perform during the task but also involves forming a representation of the actions that the co-actors might be required to make. For example, in an individual task, the agent performing the task might form a task representation that includes the fact that they will be required to make responses with both their left and their right hand. In the case of a joint task, the same representation might be formed even when one of the responses (e.g., the responses performed with the left hand) is not actually performed by the agent but is instead performed by the agent’s co-actor. That is, the agent might form a representation of the joint task as a task requiring left hand and right hand responses even when the agent is only able to produce left hand responses. Thus, it is a representation of *what* actions are to performed in th joint task.

*Task co-representation* involves an agent forming a representation of their co-actors task rules. That is, an agent forms a representation of their co-actor’s task goal, or intention, in a manner that links a particular environmental feature with a particular response. These responses can be coded in either proximal (i.e., movement intentions) or distal terms (i.e., action intentions). For example, a response can be coded as “push a button” or “turn on the light”. This differs from *action co-representation* because the content of the representations does not merely refer to the actions required for successful completion of the joint task; rather, the representations that underlie *task co-representation* make reference to the environmental features that trigger specific responses. Thus, it is a representation of w*hen* (i.e., in response to what stimulus) specific actions are to be performed in the joint task.

*Actor co-representation*, on the other hand, involves representing the agent responsible for responding to particular environmental features rather than the action required. That is, it involves representing w*ho* is required to make the response. Thus actor co-representation differs from both task and action co-representations because it contains no content that refers to the actions that are to be performed. That is, rather than representing *what* the other agent must do (for example, their action possibilities or their stimulus-response mappings), actor co-representation involves only representing *that* another agent is responsible for the other half of the task. To illustrate this distinction Wenke et al. (2011) use the example of a table tennis match. Task co-representation implies that an agent represents what stroke (e.g., top spin, back spin) their opponent with employ on each turn. Actor co-representation implies only that the agent represents that it is their co-actor’s turn rather than their own turn during specific points in the task.

Importantly, the three types of representations that can be formed during joint tasks are not mutually exclusive. Rather, each specific type of co-representation may play a role during different periods of joint task performance. Indeed evidence for each type of co-representation can be found in the joint task literature. Below we consider the evidence that supports the existence of each type of co-representation. Furthermore, we also examine an alternative explanation for the findings in the joint task literature that claims to explain the joint task effects without recourse to co-representation. This alternative explanation seeks to explain the joint tasks effects through a spatial coding mechanism. We examine the evidence that has been used to support this explanation, together with the counter evidence, and outline why this alternative explanation cannot be supported and why accounts based on co-representation are favoured.

# The joint task literature

Much of the initial work examining the nature of the representations that underlie joint tasks was done using the Simon task. In the individual version of the Simon task, a participant is asked to make a response to one feature of a stimulus (e.g., colour or pitch) while ignoring an irrelevant spatial dimension of the stimulus (e.g., location or the direction in which an arrow is pointing). A simple example might require a participant to press a button with their right hand when they see a green stimulus and another button with their left hand when they see a red stimulus. The typical finding is that when participants are asked to respond to a relevant stimulus feature while ignoring an irrelevant spatial feature of a stimulus, the spatial feature facilitates the response when it is spatially compatible with the response. For example, a response to a stimulus with the right hand might be facilitated when the stimulus is presented to the participant’s right (e.g., Simon, 1969). Importantly, this facilitation effect is not found when participants are asked to make responses that do not also have a spatial dimension. That is, if participants perform a go/no-go task, in which they are asked to make a single response to a particular colour and withhold their response to a different colour while ignoring the irrelevant spatial dimension, then the irrelevant spatial dimension of the stimulus does not influence the timing of the response.

In the joint version of the Simon task the standard two choice Simon task is distributed across two individuals with each participant responding to one colour with the other participant responding to the other colour. As participants only respond to one colour while withholding their response to the other colour each participant in effect performs a go/no-go task. Sebanz et al. (2003) found that when individuals performed the go/no-go task as part of a pair the spatial compatibility effect, which is absent during individual go/no-go performance, re-emerged. That is, the results of the joint go/no-go task mirrored the results of the individual two-choice task even though each participant was making a non-spatial response.

## The spatial coding account of joint task effects

Guagnano et al. (2010) and Dolk et al. (2011) have argued that the joint Simon effect does not tap in to social processes, but instead can be explained by the co-actor acting as a spatial reference for the participants non-spatial responses. In support of this account are the results of Guagnano et al. (2010) that demonstrated that similar effects to those observed by Sebanz and co-workers (e.g., Sebanz et al., 2003, 2005) could emerge during non-cooperative tasks. Importantly, however, these effects only emerged when the other individual was located within the peripersonal space of the participant and not when the other individual moved out of peripersonal space. This proximity, Guagnano et al (2010) has argued, is required for the other person to act as a spatial reference.

Similarly, Dolk et al (2011) has argued that the joint Simon effect is not dependent on co-representation of the co-actors action, because a manipulation designed to incorporate the co-actors limb within the participant’s body schema reduced, rather than increased, the size of the joint Simon effect. In this study, the rubber hand illusion was used to incorporate the co-actor in the participant’s body schema. In order to create the rubber hand illusion (Botvinick & Cohen, 1998), a rubber hand is placed in view of the subject near a subject’s real hand while their real hand is obscured from view. Brushes are then used to stroke the rubber hand and the real hand in either a synchronous or asynchronous manner. During synchronous stroking, the subject reports a sense of embodiment in the rubber hand. During asynchronous stroking, however, this sense of embodiment in the rubber hand does not emerge. Dolk et al (2011) argue that if the effector that has the other response is actually incorporated into the participant’s body schema (through the rubber hand illusion) then the size of the joint Simon effect should increase. That is, the size of the joint Simon effect should increase when both the left and the right response effector feel like they are part of the participant. However, the opposite occurred and the size of the effect reduced, and the size of the effect was larger in the asynchronous (no illusion) condition. Dolk et al (2011) argue that these results can be explained by the asynchronous stroking emphasizing the existence of the co-actor thereby allowing the co-actor to act as a stronger spatial reference.

### Problems with spatial coding

Unlike accounts that explain the results of the joint Simon task by making reference to social processes, the spatial coding hypothesis instead argues that these effects result from sharing space with a salient environmental feature. This salient environmental feature is a co-actor in the joint task literature; however, it need not be another agent that the space is shared with. Any salient environmental feature, even an inanimate object, should be sufficient to produce the effect. Although there is evidence, outlined above, to support the claim that spatial coding can explain at least some of the effects observed in certain versions of the Simon task, there are at least three lines of evidence that suggest that spatial coding is not able to provide a general account of the findings from the joint Simon task. First, studies in which participants perform the task with a hidden co-actor, which highlight the importance of holding the belief that one is performing the task with another agent. Second, an experiment that involves co-acting with a robot, which demonstrate that the joint Simon effect is not contingent on the mere presence of a co-actor but is instead contingent on holding particular beliefs about the intentional nature of the co-actor. And third, an experiment that inverts the direction of the joint Simon effect by instructing participants with either a response focus or an effect focus, which demonstrates that the joint Simon effect is dependent on the nature of the representation of action goals during the task and not on features of the environment. Each of these three lines of evidence are addressed below.

The first line of evidence that is difficult to reconcile the spatial coding account comes from studies performed by Tsai et al. (2008). In this study, participants individually performed a joint go/no-go Simon task under the belief that they were co-acting with a hidden human agent or a computer. In contrast to the findings of Guagonano et al. (2010), which suggested that physical proximity to a co-actor was necessary for the spatial compatibility effect to emerge, Tsai et al. found that the spatial compatibility effect could be elicited even when participants were co-acting with a hidden agent. A second finding by Tsai et al. suggest a possible reason why the spatial compatibility effect reported by Guagonano et al. was extinguished when participants moved out of peri-personal space. In particular, Tsai et al. were able to extinguish the joint Simon effect by modifying participants’ beliefs so that they believed they were co-acting with a computer rather than a human. This suggests that holding the belief that one is engaged in a joint task with another intentional agent is a precondition for co-representation to occur.

The importance of holding this belief is further underscored by findings from Welsh et al. (2007) and Vlainic et al (2010). Welsh et al. found that the joint Simon effect disappeared after the confederate left the room while Vlainic et al. found that the Simon effect remained even when co-actor was hidden. Vlainic et al. suggest that the key difference between their paradigm and the paradigm employed by Welsh et al. is that they continually reinforced the participant’s belief that they were co-acting with another agent. Thus, they argue, Welsh et al.’s failure to find the spatial compatibility effect in the hidden co-actor condition is due to participants not holding a sufficiently strong belief that they were jointly performing a task.

The importance of holding this belief can be used to explain why Guagonano et al. (2010) was able to extinguish the spatial compatibility effect when participants moved out of peri-personal space. In Guagonano et al.’s paradigm the participants performed their tasks independently and thus were not under the belief that they were jointly performing the task. The lack of this belief explains the failure to find the spatial capability effect when the two actors were not in close proximity to each other. The fact that the effect was still found when participants were seated next to each other suggests that spatial coding is an additional, rather than an alternate, cause of the spatial compatibility effects found in the joint Simon task.

The second line of research that can be used to argue against the spatial coding hypothesis as a general account of the joint Simon effect comes from a study by Stenzel et al. (2012) in which participants performed the joint Simon task with a robot co-actor. The task was performed under two conditions in which participants were given two different instructions about how the robot’s movements were controlled. In the *human-like* condition, participants were told that the robot had been designed to function in a biologically inspired manner, while in the *machine-like* condition participants were told that the robot operated in a purely deterministic manner. That is, in the human-like condition participants were encouraged to attribute human-like intentions and decision processes to the robot. A debriefing questionnaire, in which participants were required to indicate their agreement with phrases such as “The robot acted intentionally” and “The robot decided actively when to respond to a stimulus”, confirmed that this manipulation did indeed have the desired effect. According to the spatial coding hypothesis, both the human-like condition and machine-like condition should be able to produce a joint Simon effect because in both conditions the presence of the robot is able to act as a reference for spatially coding the participant’s responses. However, if the joint Simon effect is modulated by the manipulation then this might be taken as evidence for some sort of co-representation.Only when the co-actor is capable of acting according to intentions (or at least when one adopts an intentional stance toward the co-actor) are there intentions that can be co-represented. The results from Stenzel et al. support the latter account, and a joint Simon effect was only found in the human-like condition and not in the machine-like condition.

Finally, a study by Kiernan et al. (2012), in which the spatial compatibility effect in the joint Simon task was inverted in response to task instructions, is also difficult to reconcile with the spatial coding hypothesis. Kiernan et al. employed an auditory version of the Simon task that required participants to press one of two keys in response to either a high tone or a low tone presented from the left or right loudspeaker. A further manipulation was added so that when the participant pressed the response button a virtual lamp was illuminated on the contralateral side of space. For example, if the participant pressed the right button a virtual lamp would be illuminated on the left side of a computer monitor placed in front of the participants. Instead of instructing participants to press a specific key in response to the high or low tone, Kiernan et al. instructed participants to illuminate a specific virtual lamp in response to a specific tone. For instance, participants might be asked to illuminate the lamp on the left (achieved by pushing the right button) in response to a high tone. Previous studies by Hommel (1993) have shown that the Simon effect is dependent on the action goal of the participant. By presenting participants with different task instructions it is possibly to modify how they represent their goals. For example, when participants are given an action goal that refers to the response that is required (e.g., “press the left button”), the stimuli that are spatially compatible with the response effector are facilitated. However, when participants are given an action goal that refers to the effect an action will produce (e.g., “illuminate the left lamp”), then stimuli that are a spatially compatible with the effect are facilitated rather stimuli that are compatible with the response effector. The instructions to focus on the action effect thus produce an inverted Simon when button presses produce their effects in the opposite side of space.

Consistent with findings from the two choice paradigms (e.g., Hommel, 1993), Kiernan et al. (2012) found that the when the task was split between two participants who had been instructed to focus on the action effect, the Simon effect was inverted with, for example, participants seated on the right being faster to respond to tones presented on the left than tones presented on the right. This finding is inconsistent with the spatial coding hypothesis. According to the spatial coding hypothesis, participants spatially code their responses with reference to salient features in the environment. The spatial coding account would not predict that the task instructions would invert the spatial compatibility effect because left or right relative to, for example, their co-actor’s body would not change.

## Social explanations of the joint Simon task

As outlined above, accounts of the basic findings in the joint task literature that attempt to explain these effects without recourse to social processes have been unable to provide an adequate account of additional findings. Rather, these additionally findings highlight the importance of the social nature of the task and the nature of the task goals in driving the effect. However, the range of findings cannot be explained by a single unitary social explanation. Rather, at least three mechanisms, supported by action, task, and actor co-representation are required to fully account of joint task literature. These three types of representation involve specifying what actions are to be performed during the joint task, specify when those actions are to be performed, and specifying which actor is responsible which parts of the task.

### Action co-representation

The action co-representation account was put forward by Sebanz et al. (2003) to explain the initial findings from the joint Simon task. Recall that this experiment demonstrated that an agent performing an individual go/no-go task together with a co-actor performing an individual go/no-go task (in response to the agent’s no-go stimuli) performed the task as if they were performing an individual two choice task. That is, when the irrelevant spatial dimension of the stimulus was compatible with their response then their responses were facilitated. This was the case even though the agent was producing responses with only the one hand and, therefore, the responses by definition did not have a spatial dimension. This suggests that performing the go/no-go task as part of a pair was somehow able to imbue the individual’s non-spatial response with a spatial dimension. Indeed, Sebanz et al. (2003) argue that the results of the joint go/no-go task suggest that during joint task performance individuals form a joint task representation that includes not only the actions that they are required to perform as their part the joint task but also the actions that their co-actor is required to perform.

### Task co-representation

A follow-up study by Sebanz et al. (2005) was able to further elaborate on this story. In this study participants performed a modified version of the joint Simon task used by Sebanz et al. (2003). The modification was made so that the two actors could either be responding to the same stimulus feature (e.g., both responding to colour) or to different stimulus features (e.g., one responding to colour with the other responding to spatial dimension). In addition, those participants that were required to respond to the spatial dimension of the stimulus could either be required to respond to compatible stimuli (i.e., press the right button in response to rightward pointing stimuli) or incompatible stimuli (i.e., press the right button in response to leftward pointing stimuli). This setup made it possible for Sebanz et al. (2005) to disentangle the effects of action co-representation—that is, the effects that result from a participant representing their co-actor’s response possibility—and task co-representation—that is, effects that result from a participant representing their co-actor’s particular stimulus–response rules.

Of particular interest were conditions in which the participant and the co-actor were applying different rules (i.e., the participant responding to colour and the co-actor responding to pointing direction). Some trials in these conditions required responses from both the participant and the co-actor, while other trials only required responses from either the participant or the co-actor. By comparing the single response and double response trials it is possible to see the effects that arise from task representation and to compare the size of the effects that result from action co-representation and task co-representation. The effects of task co-representation can be observed in two comparisons. First, by examining those participants who are required to respond to the compatible spatial stimuli (e.g., press the right button in response to rightward pointing stimuli) it is possible to see the effects of task representation in the comparison between single response trials and double response trials. On single response trials, no conflict is created between the colour dimension of the stimulus and the response to be produced and no conflict is created between the spatial dimension of the stimulus and the response to be produced. On the double response trials there is similarly no conflict between the spatial dimension of the stimulus and the response to be produced; however, the colour dimension of the stimulus signals the alternative response to be produced by the co-actor. Therefore, the slowdown in response time observed in the double response trials results from participants representing the stimulus response rules of their co-actor and the response competition that occurs when the stimulus vicariously activates the alternative response in the participant.

Second, it is also possible to compare the single response trials and double response trials for participants that are required to respond to incompatible spatial stimuli (e.g., press the right button in response to leftward pointing stimuli). As with the participants that respond to compatible stimuli, the effects of task co-representation can be observed when comparing reaction times for the single response trials with reaction times for the double response trials. In addition to the conflict produced by task co-representation, an additional conflict produced by action co-representation is also present in both single and double response trials. This conflict occurs because when participants represent both their own response and the response of their co-actor in a single joint-task representation the actions that they produce are imbued with a spatial dimension. For example, participants seated on the right would code their own responses as RIGHT. When responding to incompatible stimuli, the stimuli that signal a participant’s own respond will possess a spatial dimension that will overlap with the spatial dimension of their co-actor’s response, thus leading to vicarious activation of the alternative response. Of course this action conflict is present in both single response trials and double response trials; however, on double response trials a task conflict also is present. Therefore, by comparing double response and single response trials for those participants that respond to the incompatible stimuli it is possible to observe the effects of response competition that occurs when the co-actor’s task rules vicariously activate the alternate response when response conflict resulting from the overlap of the spatial dimension of the co-actor’s response and the spatial dimension of the stimuli is also present.

The results of these two comparisons demonstrate the compatibility effects observed in the joint Simon task result from more than just participants representing their own and their co-actor’s action possibilities in a single system. Rather, they show that in addition to this action co-representation, participants also represent the stimulus-response rules of their co-actor. That is, they represent what actions their co-actor is required to produce in response to what features of the environment. In addition, the results also show that action conflict and task conflict interact. That is, the effects of task conflict are larger in the presence of action conflict. This is to be expected if task conflict and action conflict task both result in vicarious activation of the alternative response. With two sources of vicarious response activation the resulting response conflict is greater.

Taken together, these findings have been used to argue that during joint task performance, participants form a task representation that not only includes their own task by also includes some aspects of their co-actor’s task. In particular, the findings from Sebanz et al. (2003) suggest that participants represent not only their own action possibilities but also the action possibilities of their co-actor. While the findings from Sebanz et al. (2005) suggest that participants represent not only their own stimulus-response mappings but also the stimulus-response mappings of their co-actor.

### Actor co-representation

While action and task co-representation make reference to the actions that are to be performed during the joint task, neither type of co-representation specifies which agent is responsible for performing those actions. To specify the agent responsible for the action, actor co-representation is required. The primary evidence used to support the existence of action co-representation is provided by results from Liepelt et al. (2011) that suggest the size of the joint Simon effect can be modulated by the nature of the previous trial. Liepelt et al. found that when the previous trial was a compatible trial and the current trial was also a compatible trial then the size of the Simon was increased. Wenke et al (2011) suggest that on compatible trials, the spatial dimension of the stimulus is compatible with whose turn it is to respond thus encouraging the use of the spatial dimension as a cue for whose turn it is. When another compatible trial follows, the link between the spatial dimension and turn is maintained, thus facilitating responses.

In addition to arguing for actor co-representation as an explanation of some of the findings in the joint task literature, Wenke et al. (2011) further suggest that the actor co-representation account provides an alternative to the task co-representation account that is able to provide a more parsimonious account of findings in the joint task literature. Indeed they suggest that there has been a systematic failure to find the effects that are predicted by the task co-representation account.

Wenke et al. (2011) report a series of studies employing two-choice go/no-go tasks. The use of two choice tasks is important because if participants co-represent the stimulus–response mappings of their co-actors then the inference effects that result from this co-representation should be specific to one of the two responses available to the participant in a manner than is dependent on which one of the two responses available to the co-actor is variously activated by the presented stimulus. For example, in the two-choice go/no-go flanker task reported by Wenke et al. participants are required to presses either a left or a right button in response to a central stimulus that was flanked by two distractor stimuli. These distracter stimuli could either be the stimuli that signalled the alternative response for the participant (e.g., if the central stimulus required a left button press response the distracter stimuli would require a right button press response), the same response for the participant, or they could signal one of the two responses available to the co-actor (e.g., they could signal a left button presses response or a right button press responses), which could either be congruent or incongruent with the participant’s response. The standard finding in flanker tasks is that when a central stimulus is surrounded by stimuli that signal a response different to the response required for the central stimulus, the time needed to make the response increases. The aim of the joint Flanker task was to examine whether responses times would be influenced by distracter stimuli that “belonged” to the other agent in a manner that was dependent on whether they signalled the same response that the participant was required to produce or a different response. That is, would response times increase more when the central stimulus required a left response and distracter stimuli signalled a right response for the co-actor?

The results reported by Wenke et al. (2011) find no evidence for response time increases that are dependent on which co-actor’s two responses the distractor stimuli signal. That is, response times did not slow significantly more in the condition where the central stimulus required a left response and the distractor stimuli signalled the co-actor’s right response compared with the condition in which the central and distractor stimuli both signalled left responses. This does not fit the prediction made by the task co-representation account. According to the task co-representation account, the presence of stimuli that signalled a specific response from the co-actor should lead to vicarious activation of that specific response in the participant. That is, the nature of the response required from the co-actor should modulate the participant’s response. However, the results reported by Wenke et al. find no evidence for this modulatory effect.

According to Wenke et al. (2011) this null effect is to be expected if rather than engaging in task co-representation, participants instead engage in actor co-representation. According to the actor co-representation, participants only represent that certain stimuli single their own turn and other stimuli signal their co-actor’s turn without represent which specific response their co-actor is required to produce in response to a specific stimulus. Therefore, when a central stimulus is flanked by stimuli to which their co-actor usually responds participants experience a turn conflict (rather than a response conflict) as they are required to determine whether it is in fact their turn to respond or their co-actor’s turn. The nature of the response their co-actor is required to give to the flanking stimuli (i.e., a left button press or a right button press) has no influence on the difficultly of determining whose turn it is to respond because, according to the weak version of co-representation, participants do not represent these specifics. Furthermore, the finding that reaction times are generally shorter in response to displays in which all the stimuli “belong” to the same actor are best explained by the stimuli acting as a turn-taking cue.

However, null effects are notoriously difficult to interpret, and there may be other reasons for the failure to find significant differences in reaction times between trials on which the flanker stimuli signalled the same response and trials on which the flanker stimuli signalled a different response to the response required for the central stimuli. One reason may lie in the nature of the experimental setup. In the setup described by Wenke et al (2011) participants sat facing their co-actor. The reason for this seating position was to examine whether participants represented their co-actor’s response in an ego-centric or allo-centric coordinate frame. That is, this design was used so that it would be possible to determine whether the participant, for example, represented their co-actor’s left button press response, which is located in the right side of space, as LEFT or RIGHT. However, one potential problem with this design might be that participants may have used both coding schemes, some participants may have used one of the two coding schemes inconsistently, and different participants may have favoured different coding schemes. All these factors may have resulted in increased variability in the data, and this may explain the failure to find statistically significant differences.

Wenke et al. (2011) also report the findings of another task which investigated individual and joint task-switching. In individual task switching paradigms, where individuals have to respond to stimuli using one of two sets of rules, the standard finding is that participants are slower to respond on the current trial if the previous trial required them to apply a different rule. For example, if, on the current trial, participants are required to make a left or right button presses in response to the shape of a stimulus then they will be slower to do this if on the previous trial they were required to make left or right button press in response to the colour of the stimulus. The slowing down has been explained in terms of a conflict between activation of the previous trial’s task rule and the current trial’s task rule. This slowing down effect has been termed a switch cost.

The experiments reported by Wenke et al. (2011) sought to investigate whether switch costs would transfer between participants in a joint go/no-go version of the task. That is, these experiments sought to investigate whether participants would be slower to respond on trials that followed trials on which their co-actor was required to implement a different task rule. This transfer of switch costs between individuals is to be expected if participants represent not only their own task rules but also the task rules of their co-actor. However, o transfer of switch costs was observed. That is, no significant difference in response times was observed on trials that were preceded by trials on which the co-actor applied a different rule compared with trials that were preceded by the co-actor applying the same rule. However, Wenke et al. do report that responses were generally slower on go trials that were preceded by no-go trials regardless of what the co-actor’s task was on the no-go trial. Again, it might be possible to explain this finding in terms of turn-taking. In the joint task, the nature of the preceding trial (whether it was a go trial or a no-go trial) might at as a cue for whose turn it is to respond on the current trial. Thus, when the current trial is preceded by a no-go trial it might be more difficult to determine whose turn it is to respond and this might lead to a general slowing down.

However, it might also be the case that the findings reported by Wenke et al. (2011) are unique because the experimental setup encouraged a turn-taking approach to the task by using a very clear turn cue. This turn cue might have resulted in a clear division of labour between the participant and their co-actor when performing the task. The turn cue followed the task cue (indicating whether that current trial was to be responded to according to rule one or rule two). The aim of having the task cue precede the turn cue was so that the task cue would lead to automatic activation of the task rule before the participant knew whether they would need to implement it or not. However, the turn might have then lead to a deactivation or an extinction in the activation of this task rule as soon as the participant knew it was not their turn, and the delay introduced by fact that these were no-go trials might have led to a resetting of the system before the commencement of the go-trial. What the results of this experiment might then show is not that task co-representation does not occur but rather that the experimental setup encouraged a turn-taking approach to the task.

While the actor co-representation may able to provide an account of previous findings within the Simon task literature, there are findings from other joint tasks that do indeed rely on task co-representation for their explanation. One such example comes from the joint Navon task (Böckler, Knoblich, & Sebanz, 2012). In the individual version of the Navon task participants are asked to observe, and respond to, stimuli composed of a global dimension and a local dimension. An example of a Navon stimulus might be a several copies of the letter “S” arranged in the shape of an “F”. The standard finding is that when participants are asked to respond to one dimension by, for example, pressing the left button in response to one letter and pressing the right button is response to another letter then their responses are slowed when the irrelevant dimension of the stimulus signals a response that is incongruent with the response signalled by the relevant dimension. For example, if a participant is required to make left button presses in response to the letter “F” on the global dimension and right button presses in response to the letter “S” then responses to “F” will be slowed when the “F” is composed of small “S”s relative to an “F” composed of small “F”s.

These effects were not related to task switching. If switch costs were the primary driver of these effects then performance on a particular trial should be modulate by the nature of the preceding trial. In particular, if the decrement in performance observed when participants and their co-actors had different tasks was a result of participants covertly performing their co-actors task on the no-go trials and then switching to their own task on the go trials then the decrement in performance should be greater on switch trials (go trials preceded by no-go trials) than on non-switch trials (go trials preceded by go trials). However, no evidence of these sequential effects was observed.

Böckler et al.’s (2012) were also able to rule out an alternative explanation, that the effects were merely the result of task instructions increasing the salience of the alternate attentional focus. To rule out this possibility, a follow-up experiment, in which participants performed the task alone, was conducted. In this individual version of the task, participants saw the same instructions as the joint version; however, they were instructed that they would be performing the task alone and that the instructions were just a carryover from a previous experiment in which participants acted in pairs. In this follow-up experiment the nature of the alternative attentional focus had no effect on task performance suggesting that task instructions alone were no sufficient to drive the effect. Importantly, the effect was also dependent on being able to observe the co-actor’s stimuli. While the effect was still found when both the participant and the co-actor were observing their own, but identical, displays the effect was abolished when each actor only observed stimuli that were relevant to their responses. This suggests that it might be necessary to believe that you are attending to the same display, or at least observing the same stimuli, as your co-actor before co-representation occurs.

The findings of the joint Navon task are difficult to explain from the perspective of actor co-representation. It would only be more difficult to determine whose turn it was on a particular trial in the different focus condition if participants processed both the local and global stimuli before making their decision. This processing of both the global and local stimuli should slow responses relative to the case where participants just have to process one or the other dimension. Actor confusion would only have an effect, if any, after the point of stimulus processing. That is, actor confusion could come into play after the task rules had already been implemented.

It is, however, possible to explain the findings from a task co-representation perspective. According to this account, when engaged in a joint task, participants represent the stimulus response rules of their co-actors. Unlike the joint Simon task, where the stimulus–response rules might take the form WHEN RED PUSH LEFT, these stimulus–response rules might take the form of WHEN STIMULUS ATTEND LOCAL or WHEN STIMULUS ATTEND GLOBAL. The decrement in performance observed in the joint Navon task when the participant and the co-actor have a different focus of attention would then be the result the conflict between two task rules.

… to be continued…

# References

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*. doi:10.1037/a0027523

Botvinick, M., & Cohen, J. (1998). Rubber hands “feel” touch that eyes see. *Nature*, *391*(6669), 756. doi:10.1038/35784

Bratman, M. E. (1999). *Intention, Plans and Practical Reason*. Center for the Study of Language and Inf.

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*. doi:10.3389/fpsyg.2011.00084

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. doi:10.1016/j.cognition.2009.10.008

Hommel, B. (1993). Inverting the Simon effect by intention. *Psychological Research*, *55*(4), 270–279. doi:10.1007/BF00419687

Kiernan, D., Ray, M., & Welsh, T. N. (2012). Inverting the joint Simon effect by intention. *Psychonomic bulletin & review*. doi:10.3758/s13423-012-0283-1

Liepelt, R., Wenke, D., Fischer, R., & Prinz, W. (2011). Trial-to-trial sequential dependencies in a social and non-social Simon task. *Psychological Research*, *75*(5), 366–375. doi:10.1007/s00426-010-0314-3

Sebanz, N., Knoblich, G., & Prinz, W. (2003). Representing others’ actions: Just like one’s own? *Cognition*, *88*(3), B11–B21. doi:10.1016/S0010-0277(03)00043-X

Sebanz, N., Knoblich, G., & Prinz, W. (2005). How Two Share a Task: Corepresenting Stimulus-Response Mappings. *Journal of Experimental Psychology: Human Perception and Performance*, *31*(6), 1234–1246. doi:10.1037/0096-1523.31.6.1234

Simon, J. R. (1969). Reactions toward the source of stimulation. *Journal of Experimental Psychology*, *81*(1), 174–176. doi:10.1037/h0027448

Stenzel, A., Chinellato, E., Bou, M. A. T., del Pobil, Á. P., Lappe, M., & Liepelt, R. (2012). When Humanoid Robots Become Human-Like Interaction Partners: Corepresentation of Robotic Actions. *Journal of Experimental Psychology: Human Perception and Performance*. doi:10.1037/a0029493

Tsai, C.-C., Kuo, W.-J., Hung, D. L., & Tzeng, O. J. L. (2008). Action co-representation is tuned to other humans. *Journal of Cognitive Neuroscience*, *20*(11), 2015–2024. doi:10.1162/jocn.2008.20144

Vlainic, E., Liepelt, R., Colzato, L. S., Prinz, W., & Hommel, B. (2010). The Virtual Co-Actor: The Social Simon Effect does not Rely on Online Feedback from the Other. *Frontiers in Psychology*, *1*. doi:10.3389/fpsyg.2010.00208

Welsh, T. N., Higgins, L., Ray, M., & Weeks, D. J. (2007). Seeing vs. believing: Is believing sufficient to activate the processes of response co-representation? *Human Movement Science*, *26*(6), 853–866. doi:10.1016/j.humov.2007.06.003

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*, 147–172. doi:10.1007/s13164-011-0057-0

Wolpert, D. M. (1997). Computational approaches to motor control. *Trends in Cognitive Sciences*, *1*(6), 209–216. doi:10.1016/S1364-6613(97)01070-X