Title: Joint task representations

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# 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

Philosophers, in attempting to provide an account of what distinguishes joint action from cases of individual action, have often invoked the notion of shared intentions. The form that these shared intentions take has differed greatly between authors: For example, Tuomela (2005) provides an account of shared intentions in terms of participants intending in a “we-mode” (to contrast with the “I-mode” of individual intentions). During a joint action each participant takes the perspective of being a member of a group and endorsing propositions such as “We together will do X” and “I will participant in our jointly doing X”. Searle (1990) provides an account that is based on the notion of the “we” intention. [Provide a short (couple of sentences) description of Searle’s “we” intention.]. Finally, Bratman (1993) [Provide a short description of Bratman’s shared intentions: e.g., I intend that we A + appropriate meshing of subplans etc].

# Intention heirachies

While the shared intentions that have been proposed to underlie joint action are often spelled out in terms of representations with propositional content it is not the case that all intentions have propositional content. Rather, intentions may be organised in a hierarchy with intentions at different levels of the hierarchy possessing different content and performing different functions. [This section will provide an outline of some intention hierarchies including Bratman(1987), Searle (1983), and finally Pacherie (2006). I think the focus should be on Pacherie. Be clear on the types of content at each level and the function of the intentions at each level. It should be clear that as one moves down the intention hierarchy there is greater/clearer specification of the means by which an action will be performed.]

# Sharing motor intentions

[If the work on automatic imitation paradigms is included then it will probably go in here. This work, in particular Liepelt et al. (2008) and Liepelt and Brass (2010), demonstrates that the beliefs one holds about the prior intentions of an observed agent result in the formation of motor representations consistent with those prior intentions. For example, Liepelt et al. (2008) examined reaction times in response to a symbolic cue while participants also observed an irrelevant hand stimulus. The symbolic cues indicated the finger that the participant was to raise to make their response and the hand stimulus could either produce a movement that was congruent with the participant’s response or incongruent with it. Liepelt et al. examined response facilitation for actions performed under two contexts. In the attempted movement condition (AMC) the stimuli contained a hand with restrained fingers so that the fingers could not be fully raised, while in the micromovement condition (MMC) the hand performed the same small movement, but the restraints were absent. The two conditions were designed so that the observers would infer two different prior intentions while maintaining a kinematic match for the movements. In the AMC, observers would be able to infer a prior intention of fully raising the finger, and they would thus form a corresponding motor representation consistent with the motor representations that underlie the participants own movements on the task. While in the MMC, observers would be inclined to infer that the hand had not attempted to fully raise the finger, and that it had the prior intention of producing a different set of movements. As a result, the corresponding motor representations that would be formed would not be consistent with the participant’s own motor representations formed when performing the task. As a result, not facilitation of responses should be expected. The results were consistent with this prediction, and facilitation was only observed when ascribed prior intentions, and thus generated motor intentions, were consistent with the motor intentions required to perform the task. This description of Liepelt’s task would be preceded by a more general description of automatic imitation tasks in general.]

# The joint task literature

While the results of automatic imitation paradigms suggest that intention ascription can lead to the formation of shared motor intentions, these findings do raise the question of whether the effects observed do indeed suggest that motor intentions are shared during joint action or whether these effects are merely an artefact of action observation. To address this question, researchers have sought to examine performance during more truly joint tasks. One such example of a joint task is the joint version of the Simon task.

In the individual version of the Simon task, the 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 blue stimulus and another button with their left hand with 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. 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.

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). [Provide a more detailed description of Sebanz et al. 2005, and outline how it shows that actors represent the specific stimulus-response rules of their co-actors].

# Alternative explanations of the joint task literature

The results of the joint Simon task have, however, not been without controversy and at least two alternative explanations have been presented to account for these findings. For example, Guagnano et al. (2010) and Dolk et al. (2011) have suggested that the effects of the joint Simon task might be explained by the co-actor acting as a spatial reference. 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 actor, 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.

In addition to the spatial coding hypothesis, another alternative interpretation has also been suggested for the findings of the joint Simon task. According to this account, known as the actor co-representation account, the results of the joint Simon task can be explained by the conflict that arises in determining whose turn it is to respond (Wenke et al., 2011). According to the actor co-representation account, rather than representing *what* the other agent must do, participants merely represent *that* another agent is responsible for the other half of the task. That is, the shared representations that underlie the joint Simon effect do not have content that specifies the means that the co-actor will employ to realise their part of the task. To illustrate the difference between actor co-representation and task co-representation Wenke et al (2011) introduce the example of a table tennis game. Task co-representation implies that an agent represents what stroke (e.g., top spin, back spin etc) their opponent will employ on each turn. Actor representation, on the other hand, merely implies that an agent will represent that it is their co-actors turn rather than their own turn. In the original version of the joint Simon task employed by Sebanz et al (2003) the finger stimulus may have acted as a cue for whose turn it was to respond and, therefore, the increase in the reaction time for the incompatible trials may have arisen because of conflict created by responding when it was “the other’s turn”. In support of this explanation, Wenke et al. (2011) cite the 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.

While each of the three accounts—task co-representation, actor co-representation, and spatial coding—are able to account for some findings within the joint task literature none of the three accounts provide a complete account of all the findings. For example, a series of results that demonstrate that it is possible to elicit spatial compatibility effects in a go/no-go task when the task is performed jointly with a hidden co-actor are difficult to reconcile with the spatial coding hypothesis. Similarly, results from other joint tasks, such as the joint Navon task (Böckler, Knoblich, & Sebanz, 2012), are difficult to reconcile with the actor co-representation account.

## Problems with spatial coding

One study that is difficult to reconcile with the spatial coding account was 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. Some might be tempted to argue that spatial coding might still be able to explain the hidden co-actor findings if it is assumed that the imagined other is sufficient to act as a spatial code. However, it is difficult to see what would then distinguishes this account from a co-representation account that holds that an actor’s responses gain a spatial dimension because their responses are coded as being the left or right part of a pair of responses performed by them and their co-actor. This would certainly not fit with Dolk et al.’s (2011) claim that joint Simon effect “is not really social in nature”.

## Problems with actor co-representation

Findings that are difficult to reconcile with the actor co-representation account come from findings produced using another joint task, the joint Navon task. 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”. [This section will outline the Navon task and Böckler et al.’s (2012) joint Navon task, including detailing how the findings of the joint Navon task are not consistent with the predictions of the actor co-representation account. In particular, this will stress that an account based purely on turn confusion (i.e., actor co-representation) would not predict any differences between the different focus and same focus conditions].

# Types of task sharing

[This section will argue that rather than providing support of a single account over other accounts the joint task literature instead point to three types of sharing that can occur when performing a task with another person. These are: 1) sharing space, but without sharing the task (spatial coding), 2) sharing the task, but actions don’t need to mesh, 3) sharing the task, and actions need to mesh (i.e., need to predict the others actions). This section will outline each of the three types of task sharing, provide an example of each type, and it will show how the joint task literature provides evidence for each type of task sharing. Finally, this section will also attempt to link back the two co-representation accounts (and the two types of sharing that they provide evidence for) to the intention hierarchies discussed in the introduction. The aim of this will be to show that different types of task sharing are the result of shared intentions at different levels of the intention hierarchy.]

# Conclusions

# [Some sort of conclusions section to finish things off].

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