Title

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Authors

Sebanz, Natalie
Knoblich, Gunther
Prinz, Wolfgang

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Your Task is my Task:
Shared Task Representations in Dyadic Interactions

Natalie Sebanz (sebanz@psy.mpg.de)
Günther Knoblich (knoblich@psy.mpg.de)
Wolfgang Prinz (prinz@psy.mpg.de)
Max Planck Institute for Psychological Research, Amalienstr. 33
80799 Munich, Germany

Abstract

While some cognitive scientists regard social interactions as just another form of environmental interaction, others have proposed that social interactions place special demands on the cognitive systems involved, and may have shaped individual minds in particular ways. One consequence of the demands of action coordination between several individuals could be that in social interactions, others' tasks are represented and integrated in one's own action plans even when coordination is not required. To test this assumption, we investigated the performance of pairs of participants carrying out complementary and different tasks alongside each other, and compared this to performance in exactly the same tasks carried out alone. The task of another agent influenced individual performance in the group setting. Performance was also modulated by the nature of the other's task. This suggests that individuals shared task representations and integrated each other´s task in their own action planning. The results are consistent with the view that the demands of joint action have shaped mental processes, and support the claim that cognition must be studied in relation to social context.

Introduction

As a proponent of the situativity of cognition, Greeno (1998; Greeno & Engle, 1995) advocated that for a full understanding of human cognition, two different lines of research that have developed in relative isolation from each other need to be integrated: one is the study of individual cognition, the other the study of social interactions. Whereas the first focuses on information processing in single individuals and pays little attention to the demands imposed by the interactions in which people engage with each other and their environment, the latter analyses patterns of coordination of activity, but does not specify how informational contents of interaction are involved in achieving task goals. This paper makes an attempt to bring these two lines together and to investigate the mechanisms underlying the emergence of shared task representations in dyadic interactions.

Embodied, Distributed, and Joint Cognition

During the last years, more and more cognitive scientists have started to favour the idea that the mind cannot be understood independently of its relation to a body that interacts with other agents and its environment (e.g., A. Clark, 1997; Spivey, 2000; Varela, Thompson, & Rosch, 1991). Much of the research inspired by the notion of embodiment has focused on individual cognitive systems and their continuous environmental couplings. Social interaction has mostly been regarded as just another form of environmental interaction. However, some approaches have propagated the view that social interactions, in particular those involving the coordination of actions, may place special demands on the cognitive systems involved.

According to the distributed cognition approach (Hutchins, 1991; 1995), these demands are best captured from a group perspective. Cognition is not regarded as an activity of a single mind, but instead as distributed across the interaction context. Hence, instead of focusing on processes acting upon representations in individual minds, the same cognitive concepts are applied to the interactions among a number of agents. It is assumed that cognitive systems consisting of more than one individual have cognitive properties that cannot be reduced to the cognitive properties of individual persons. Thus humans coordinating their actions can reach goals that are beyond the capabilities of any individual member. The coordination of distributed knowledge and tasks is a major demand on the group. It is assumed that coordination is achieved through shared representations of goals.

The question of how individuals coordinate their actions to reach a common goal has been addressed in more detail in Clark's work on joint action (1996). Clark does not share the radical claim of distributed cognition that representations must be investigated at the group rather than at the individual level. However, his approach is also based on the view that the results of joint action cannot be explained by analysing individual actions, and that the individual mind must be studied in the context of its social interactions. According to Clark, coordination depends crucially on the knowledge, beliefs and suppositions – in short, the common ground - shared by people acting together. This shared basis is needed to form mutual expectations about the actions the other will take. Common ground emerges from two different sources: On the one hand, it is based on the joint conceptual knowledge people bring with them, such as knowledge about social norms. On the other hand, common ground develops in the course of a joint action due to joint perceptual experiences, such as observed changes in the environment.

The latter aspect has been investigated empirically in a study on real time action coordination in groups (Knoblich & Jordan, 2000). The main finding was that members of a group learned to extend the temporal horizon of their planning by relying on changes in the environment, but only when they received unambiguous timing information about the other's actions. Clearly, the need to rely on external cues for anticipating future events is specific to groups, as individuals can relate conflicting actions to future events within the system. The authors speculated that the need to rely on changes in the environment for joint action may have fostered the emergence of cognitive systems that are capable of integrating effects of others' actions into the planning of one's own.

Sharing Task Representations

The division of labor and the coordination of individual actions to reach common goals seem to place special demands on groups and the individuals that are part of them. From the perspective of individual group members – on which we will focus in the following - , the challenge is to form shared goal representations with other group members that allow one to coordinate distributed knowledge and tasks. In real-time coordination, others' actions or their effects must be predicted in order to coordinate one's own actions with theirs. These demands may have shaped individual minds both phylo- and ontogenetically to make them especially apt at observing and understanding others' actions (Blakemore & Decety, 2001). One further consequence of this social embodiment process (Barsalou, in press) may be that in social interactions individuals continuously monitor each other's actions and attend to each other's tasks, anticipating that they might need to engage in joint actions and thus may have to coordinate their actions at some point. Thus, shared representations in groups may arise even in situations where coordination is not required, and where the optimal performance strategy for each individual would be to ignore the task or the actions of other persons.

Experiment

To address this issue, we investigated the performance of pairs of participants carrying out a task alongside each other, and compared this to performance in exactly the same task carried out alone. Any changes in performance between the individual and the group setting must be due to the fact that participants in the group integrate the other's actions or task into their own action plans in some way. This integration could either take place at a very general level, in the sense that one represents the other as an agent, or in a more specific way, e.g., by sharing a representation of the other's task.

To distinguish between these two possibilities, we distributed the two action alternatives of a spatial compatibility reaction time (RT) task (Simon, 1990) among two participants, so that each participant performed a go-nogo task. There were two different group conditions: in one condition, participants performed complementary tasks, responding to the same stimulus feature. In the other, they performed different tasks, acting upon different stimulus features. If a general representation of the other as an agent is formed, then there should be no difference between the two group conditions. However, if one shares the task representation with the other person, then one's own performance should be affected by the nature of the other person's task.

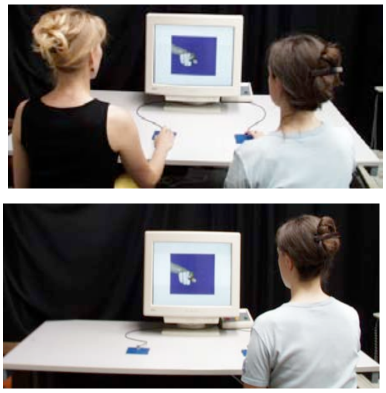

Figure 1: Setting in the joint go-nogo condition (top), and in the individual go-nogo condition (bottom).

We used pointing stimuli because processing of these stimuli is known to be sensitive to the social context (Tomasello, 1995). Participants were presented with pictures of a hand pointing left or right. A red or a green ring was attached to the index finger of the hand. Each participant responded to one of the two colors, or to one of the two pointing directions, respectively, so that the task was always a go-nogo task. When color was task-relevant for a participant, the pointing direction was irrelevant for him or her, and vice versa. Responses were given as fast as possible with a button press. In the group setting (Fig. 1, top), one participant was sitting on the left and the other was sitting on the right. In the single person setting (Fig. 1, bottom) each participant carried out exactly the same task as in the group setting, while the other person's chair remained empty.

There were four different conditions. The go-nogo task in response to color was performed alone (individual color), and the go-nogo task in response to pointing direction was performed alone (individual pointing). The go-nogo task in response to color was performed alongside another agent responding to the other color (joint color), and alongside another agent responding to pointing direction (mixed-task).

The optimal perfromance strategy for the group conditions would be to ignore the other agent's task, because it is not relevant for one's own task and may even lead to interference. If participants pursue this strategy, there should be no difference between their performance in the individual and the respective group settings. However, if the other agent is represented and integrated in one's own action plan, this should manifest itself through interference effects in the joint tasks that are not present when the same task is performed alone.

For the joint color condition the following results can be predicted: given the social nature of pointing stimuli (Tomasello, 1995), it is likely that the pointing finger will take on the affordance of a turn taking signal in the group. One may automatically interpret the finger pointing at oneself as an indicator of one's own turn, and regard the finger pointing at the other participant as a signal for the other's turn. Thus actions should be faster on trials where the finger points at oneself (compatible trials), and slower on trials where it points at the other agent (incompatible trials). Assuming that the presence of another agent evokes or increases the turn-taking affordance of the pointing stimuli, this effect should be much weaker or absent in the individual color condition.

In the mixed-task condition, where one person responds to color and the other to the pointing direction, the compatibility effect for the person responding to color may be even stronger, because the pointing direction that is irrelevant for both participants in the joint color condition is now relevant for the other participant. An increase in the size of the compatibility effect is only to be expected, however, if the task representation of the other person is shared. If the other is only represented as an agent in a general way, i.e., as somebody who performs a task that is not further specified, then there should be no difference between the two group conditions.

Finally, for the pointing task, the following predictions can be made. In the individual condition, where responses are always given to one pointing direction, the irrelevant color cue should not have any effect on RTs. In the mixed-task condition, it is conceivable that one represents the color task of the other participant and associates the other's color with his or her actions. Thus RTs on trials where one needs to respond although the irrelevant color cue also requires an action from the other participant may be slower, compared to trials where the irrelevant color cue does not require an action from the other person. This effect may be more pronounced in the condition where the person responding to the pointing direction responds whenever the finger points at the other participant, and not when it points at her- or himself. The reason is that in this condition, the contingency between the pointing direction and the other's actions may increase the turn taking affordance of the stimulus and thus lead to increased response conflict.

Method

Participants Thirty-two paid participants (7 male, 25 female) recruited by advertising at the University of Munich, Germany, and in local newspapers took part in the experiment. All were right-handed and had normal or corrected-to-normal vision.

Materials and Procedure Half of the participants were assigned to the color group, half to the pointing group. Participants in the color group performed the following conditions: 1) individual color, 2) joint color, 3) mixed-task (responding to color alongside a person responding to pointing direction), 4) individual pointing. Participants from the pointing group performed the following conditions: 1) individual color, 2) joint color task, 3) mixed task (responding to pointing direction alongside a person responding to color), 4) individual pointing. Half of the participants in the pointing group always responded when the finger pointed towards them (pointing-towards condition, n=8), and the other half always responded when the finger pointed away from them (pointing-away condition, n=8).

The order of the four conditions (individual color, joint color, mixed-task, individual pointing) was counter-balanced across pairs of participants. In the joint conditions, participants sat side-by-side in front of a monitor with a distance of 40 cm between them. In the individual conditions, an empty chair remained beside them (see Fig. 1).

Participants responded to digital photographs of a right hand pointing either to the left or to the right. On the index finger there was a clearly visible ring colored red or green (see Figure 1). The stimuli were presented centrally and the ring always appeared at exactly the same location. Picture size was about 15 x 13 visual degree horizontally and vertically. Each participant was instructed to respond to one of the two colors or pointing directions by pushing a single button. All participants used their right hand do respond.

The sequence of events in each trial was as follows: A black fixation cross appeared on the screen for 100 ms, followed after 100 ms by a picture of the hand. The picture disappeared after 500 ms. The RT interval was 1000 ms from picture onset. The next trial was initiated after 500 ms. In each condition, participants completed 4 blocks of 100 trials. Each of the stimuli appeared an equal number of times within each block, and the order of stimulus presentation was random. Stimulus presentation and data collection were controlled by an Apple Power PC. The pictures were presented on an Apple 21" monitor with a horizontal resolution of 1024 and a vertical resolution of 768 pixels.

Results

We first present the results for the color tasks, followed by the pointing tasks. Figure 2 shows the results for responses to color only. From left to right, the panel shows mean RTs on compatible and incompatible trials in the individual color condition, the joint color condition and the two mixed-task conditions (pointing-towards and pointing-away). Note that the two mixed tasks were between-subjects, whereas the other tasks were within-subjects. The error rates in all four conditions were below 5% and were not analysed further. Error trials and RTs greater than 600 ms were excluded from the statistical analyses.

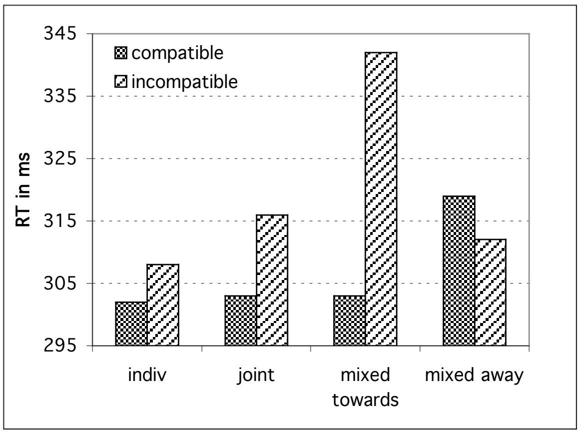

Figure 2: Mean RTs for responses to color in the individual color, the joint color, and the two mixed-task conditions.

In order to assess the statistical significance of the RT differences, 3 within-subjects 2 x 2 ANOVAs with the factors Condition (see below) and Compatibility (compatible and incompatible) were performed: one for the individual and joint color condition, one for the joint color and the mixed-task condition where the person responding to pointing direction responded when the finger pointed at her- or himself (pointing-towards), and one for the joint color and the mixed-task condition where the person responding to pointing direction responded when the finger pointed away (pointing-away). Finally, for the mixed-task conditions a between-subjects 2 x 2 ANOVA with the factors Pointing Task (pointing-towards versus pointing-away) and Compatibility (compatible versus incompatile) was also performed.

Individual and Joint Color There was no significant difference in RTs between the individual and joint color condition, F(1, 31) = .70, p = .41. The main effect for Compatibility was significant, F(1, 31) = 43.37, p < .001. As can be seen in Figure 2, there was also a significant interaction between the factors Condition and Compatibility, F(1, 31) = 7.46, p < .05. The compatibility effect was larger in the group setting.

Joint Color and Mixed-Task (Pointing-towards) Again, there was no significant difference in RTs between the two different conditions, F(1, 7) = 1.42, p = .27. The main effect for Compatibility was significant F(1, 7) = 26.10, p <.01. As can be seen in Figure 2, the interaction between the factors Condition and Compatibility was also significant, F(1, 7) = 27.09, p < .01. The compatibility effect was considerably larger in the mixed-task condition.

Joint Color and Mixed Task (Pointing-away) There were no significant differences, all p >.05.

Mixed-Task (Pointing-towards vs. Pointing-away) There was no significant difference in RTs between the two conditions, F (1, 14) = .31, p = .59. The main effect for Compatibility was significant, F (1, 14) = 14.88, p < .01. There was also a significant interaction between the factors Pointing Task and Compatibility, F (1, 14) = 30.58, p < .001. Post-hoc tests (Newman-Keuls) showed that there was a significant difference in RTs on compatible and incompatible trials in the pointing-towards condition, p < .001, but not in the pointing-away condition, p = .18.

Results Pointing Tasks

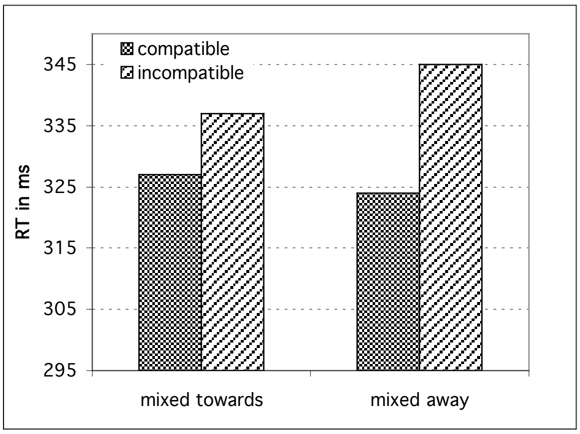

Figure 3: Mean RTs for responses to pointing direction in the two mixed-task conditions (pointing-towards and pointing-away).

A two-sided t-test for paired samples showed that there was no significant difference in the general RT level between the individual and the group setting. Further t-tests showed that responses to pointing direction were faster compared to responses to color both in the individual and the group setting, p < .05.

In the mixed-task condition, trials were coded as compatible and incompatible from the point of view of the participant responding to pointing direction. Compatible trials were defined as trials where the ring color was complementary to the color the color-person was instructed to respond to, whereas incompatible trials were such where the color required a response from the color-person. E.g., when the color person was instructed to respond to red, compatible trials for the pointing-person were trials on which the ring was green, and incompatible trials were ones on which the ring was red.

Figure 3 shows the results for responses to pointing direction in the two different mixed-task conditions. From left to right, the panel shows mean RTs on compatible and incompatible trials in the pointing-towards and the pointing-away condition.

A 2 x 2 ANOVA with the within-factor Compatibility (compatible versus incompatible) and the between-factor Pointing Task (pointing-towards versus pointing-away) was conducted. There was a significant main effect for Compatibility, F (1, 14) = 38.23, p <.001. The interaction between Pointing Task and Compatibility was marginally significant, F (1, 14) = 4.42, p = .05. The compatibility effect was larger in the pointing-away than in the pointing-towards condition.

Discussion

The observed interaction between setting and compatibility in the joint color task suggests that in the group, the pointing stimulus gained the affordance of a turn-taking signal, leading in particular to slower responses when the finger referred to the person not to respond. This change in the affordance of the pointing stimulus can be explained by the assumption that the other is represented as an agent who performs part of the task.

From this result it cannot be concluded, however, in what way the other is represented. Is he or she represented as someone who generally performs a part of the task, or is the concrete task of the other person represented? The comparison between the joint color condition and the mixed-task conditions allows one to address this issue. The fact that the compatibility effect increased when the other participant responded to the pointing direction suggests that the task of the other person became part of one’s own action plan. Interestingly, the effect only increased when the other person responded to pointing stimuli pointing at her- or himself. This finding is in line with our turn-taking account. When the pointing-person responds to stimuli pointing at her- or himself, the turn taking affordance of the pointing stimulus is reinforced for the color-person, due to the contingency between the pointing direction and the other’s actions. Hence, on incompatible trials, where one has to respond although the finger points at the other person, one’s own action will be inhibited. The slower RTs on incompatible trials reflect the time it takes to overcome this inhibition. However, when the pointing-person responds whenever the finger points at the color-person, there is no response conflict for the color-person, and thus no increase in RTs on incompatible trials.

The results for responses to pointing direction in the mixed-task conditions also provide evidence that the task representation of the other participant was shared. The fact that RTs on trials where the irrelevant color cue also required an action from the other participant were slower compared to trials where the irrelevant color cue did not require a response from the other person, suggests that the color was associated with the other’s actions. In line with our predictions, the effect was stronger in the pointing-away condition. We assume that in this condition, the contingency between the pointing direction and the other’s actions enhanced the turn-taking affordance of the stimulus and thus led to increased response conflict.

One may argue that RT differences in the mixed-task conditions were due to the fact that on some trials, only one action was required, whereas on others, a response from each of the two participants was required. Two results speak against this interpretation, however. First of all, responses to pointing stimuli were faster than responses to color. Thus on trials where both participants responded, the anticipated actions of the other rather than the actual responses must have influenced the pointing-person´s actions. To anticipate the other’s actions, the task must be represented. Second, if the observed compatibility effect for responses to pointing direction were only due to differences in the responses, then the effect should be the same in the two different pointing conditions, because in both, incompatible responses are associated with two actions. Instead, we observed an interaction between pointing task and compatibility.

Conclusions

The results clearly show that the optimal performance strategy, which would have been to ignore the other person, was not pursued. Rather, our findings provide evidence that individuals share task representations with another group member and integrate the other’s task in their own action planning. This sharing of task representations was observed in a situation where coordination was not required, and where the task could equally well be performed on one’s own.

It is tempting to speculate that this automatic emergence of shared task representations in dyadic interactions has its origins in the need to coordinate one’s own actions with others’. As pointed out by Clark (1996), one of the most important prerequisites for joint action is common ground. Actions can only be coordinated when one is able to predict what the other will do. Clark focuses mainly on the use of joint declarative knowledge in discourse to show how common ground is built. However, in non-linguistic action domains, there may also be other ways of establishing a mutual basis for joint action. One way to conceptualize this is to assume that individuals learn to anticipate each other's actions through distal events (Knoblich & Jordan, in press). Predictions can be based on contingencies between one's own actions, others' actions, and jointly controlled events. This implies that individual action plans are extended to include the anticipated actions and action effects of others.

In the non-linguistic action domain, a great number of tasks consists of well-defined subtasks that are distributed among different agents. For example, think of two people pitching a tent and trying to drive a peg into the ground. One person needs to grasp and pull the rope attached to the tent, while the other drives the peg into the ground with a hammer. In joint actions where pre-defined tasks are distributed, the best way to anticipate others' actions is to represent their task. This can be achieved in different ways: one may simulate the actions to be performed by the other, or one may form a representation of the task in terms of the distal events that are caused by the other's actions (Knoblich & Jorden, in press). In both cases, shared task representations establish the common ground for joint action. Creating shared task representations can thus be regarded as one of several special demands on individuals coordinating their actions. It is possible that this demand has shaped cognitive systems in a way that individuals cannot help observing others' actions and their effects, and integrating them in their own action planning when possible. This should apply especially when the task of another person is easy to grasp and the demands on working memory are low, as was the case for the tasks we used in our experiment.

The social situation we created in our experiment seems to be quite different from everyday interactions in that the tasks to be performed were very simple and the two agents did not need to coordinate their actions. However, we believe that studying social situations with minimal coordination requirements allows one to capture the basic elements of more complex interactions, such as the emergence of shared task representations, shared goals, and shared action planning. According to Greeno (1998), there are two ways of integrating the study of individual cognition and social interactions. One is to expand the framework of cognitive science by studying mental processes in social context, the other is to begin with a framework of interactional studies and zoom in on specific processes occurring in the group. We believe that studying mental processes in individuals during social interactions is a promising way to investigate how social context has shaped the mind, and to tackle processes that may occur specifically in social situations.

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