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How does Task Sharing Influence Individual's Performance? An Investigation with Interference Paradigms

By

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CIMeC
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to my cousin, Alberto

Abstract

In this thesis I investigated whether and to what extent performing a task with another person may change individual cognitive performance. Interference paradigms are particularly suitable for addressing this issue. The rationale behind the use of these paradigms is that most of them can be split in two complementary or independent tasks assigned to two different individuals. By comparing task performance when participants act in the joint context and when they perform the task individually, important information may be derived about whether the co-actor's task is represented and how this representation influences one's own performance.

Following this approach, I adopted the joint version of two different and well-known paradigms: the picture-word interference paradigm (Study 1: Experiments 1, 2, 3) and the Simon task (Study 2: Experiments 4, 5, 6). Both paradigms allow understanding how people can deal with the task irrelevant information when the accomplishment of the task is achieved in a joint (and cooperative) context.

The results of both studies provided converging evidence showing that, regardless of the paradigm used, task sharing determines the disappearance of the interference effect produced by the task irrelevant information (Study 1) or by the (incidental) spatial representation of an alternative response (Study 2). The disappearance of the interference effects, however, occurred only when the co-actor was thought to work on

different or complementary stimuli but not when s/he was in charge of the same stimuli as the participant.

These findings will be accounted for by taking into consideration both the specific peculiarities of each paradigm exploited and the strategic processes of division of labor that can be established between two co-acting individuals.

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Theoretical background

Studies in cognitive psychology have long been directed to investigate human cognitive functions in environments in which participants act in isolation. Studies conducted in experimental psychology labs, indeed, do not usually admit the involvement of people other than the individual under investigation. The presence of other people is commonly considered as a source artifacts, which has to be absolutely avoided. It is worth noting, however, that in everyday life we rarely engage in activities that do not imply the presence or the involvement of other people. We are social beings and we perform actions in environments penetrated with social interactions. As a consequence, our actions are necessary influenced by the presence of other people, the kind of relationships we have with them and their specific actions. In the light of this fact, in the last decades cognitive psychology has started to take into consideration the influence of these variables on human cognition and actions. What has been traditionally considered as an artifact, in this new perspective is seen as a fundamental variable that deserves to be investigated.

In this respect, two different research areas can be distinguished: social facilitation and joint action. The main difference between these two lines of research is that social facilitation area investigates how participants' performance is influenced by the presence of another person performing simultaneously and independently the same task as the participant (i.e., two participants performing the same task in the same room without co-acting, that is, independently of one another); in contrast, joint action[1] area refers to actual interactive conditions in which two participants take care of two different (and/or complementary) aspects of the same task. In the following sections I summarize the main studies and the relevant results characterizing these two different areas of research.

1.1 SOCIAL FACILITATION

Social facilitation is one the oldest concept in social psychology (Allport, 1920; Bond & Titus, 1983)[2]. Social facilitation theory focuses on the changes that occur when individuals perform tasks alone or in presence of real, imagined or implied others: an audience (i.e., people in the same room where the participant is performing his/her task) or co-actors (i.e., persons performing independently the same task as the participant). Several social facilitation studies have unequivocally demonstrated that task performance is affected differentially by social presence. Typically, performance is

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[1] Joint action research embraces several aspects of human interactions (see Knoblich, Butterfill, & Sebanz, 2011, for a review). An extensive review of all the studies and paradigms related to the joint action area is beyond the purposes of this thesis. As a consequence, in this chapter I focus only on the literature related to the joint Simon effect.

[2] The development of social facilitation theory can be traced back to Triplett's study (1898). Triplett noticed that bicycle racers were faster when they raced against other cyclists then when they raced alone. At first blush, Triplett attributed the improvement of performance to the competitive context and to the increase in the motivation that might characterized this kind of contexts. The introduction of the term social facilitation, however, owes to Allport (1920), who extended Triplett's (1898) research by attempting to minimize the role of competition.

facilitated in simple tasks, whereas it is impaired in difficult tasks (Aiello & Douthitt, 2001; Guerin, 1993).

Over the years, different interpretations have been proposed to account for these effects. According to the traditional interpretation, the presence of others increases the general drive and the activation level of the actor (*generalized drive hypothesis*; Zajonc, 1965). In Zajonc's view, increasing in activation is an innate reaction that would allow people to promptly respond to any potential unexpected actions by others. The increase in activation level enhances the dominant-response tendency: It facilitates dominant responses (i.e., those responses that have priority in one's own behavioral repertoire) and it inhibits subordinate responses. In simple (or well-learned) tasks, the dominant response is the correct one, which leads to performance improvement. In contrast, in difficult (or not well-learned) tasks, the dominant response is the wrong one and, as a consequence, performance is impaired.

Few years later, Zajonc's theory was brought into question by Henchy and Glass (1968), who argued that the presence of others is not sufficient to induce social facilitation. In contrast to Zajonc's hypothesis, these authors claimed that the increase in individual arousal induced by social presence is not an innate response but it occurs only when the individuals are afraid that their performance will be evaluated (*evaluation apprehension hypothesis*; see also Cottrell, Wack, Sekerak, & Rittle, 1968 for an extension of this theory, the *learned drive hypothesis*).

In the 80s, the role of attention was emphasized. According to the *distraction-conflict hypothesis* (Baron, Moore & Sanders, 1978) the presence of others has a distracting effect, thus hampering participants to completely focus their attention on the task. This turns into an increase in activation, arising from a conflict between the others and the task, which always impairs performance on difficult tasks. Whereas performance on simple tasks can either improve or decrease depending on the number of distractors in the environment and, thus, the size of activation: the more distractors are, the worst performance is.

The *overload hypothesis* (Baron, 1986) can be considered as a modified version of the *distraction-conflict hypothesis*, as it states that the distraction induced by the presence of others does not lead to an increased arousal but rather it gives rise to a cognitive overload. Cognitive overload, in turn, causes a restriction of the focus of the attention, resulting in performance facilitation when the task is simple or requires attention to a small numbers of elements, and in performance impairment when the task is complex or requires paying attention to many elements. Performance increases on simple tasks because cognitive overload allows participants to focus their attention on the relevant stimuli and to filter out irrelevant information.

In contrast, on difficult tasks, which usually consist of several stimuli that tie up attention, performance decreases because participants might neglect stimuli that are crucial to perform the task.

Empirical evidences in support of the attentional theories of social facilitation have been obtained by employing one of the best-known interference tasks in cognitive psychology: the Stroop task (Stroop, 1935). In the next paragraph I review relatively recent experimental studies supporting the attentional view of social facilitation.

1.1.1 Social presence influence on the Stroop effect

The standard Stroop task requires participants to name the color of the ink with which a letters string is printed. Typically, RTs are slower when the string is a color name incongruent with its ink color (e.g., when the word green is shown in red) as compared to neutral trials (e.g., when a string of Xs is displayed in red), a phenomenon known as Stroop interference (MacLeod, 1991). The occurrence of this interference has been traditionally attributed to the fact that reading is automatic and that skilled readers cannot refrain from accessing word meaning (Besner, Stolz, & Boutilier, 1997). Importantly, the presence of such an effect is a clear example of interference arising from a conflict between an automatic (uncontrolled) cognitive process (word reading) and a relatively controlled cognitive process (color naming).

The Stroop task is particularly appropriate to disentangle between the two main hypotheses advanced to explain social facilitation effects, that is, the *generalized drive hypothesis* (Zajonc, 1965) and the *distraction-conflict hypothesis* (Baron et al., 1978). Indeed, on the basis of these two hypotheses, opposite effects are expected when participants perform the Stroop task in presence of others. Specifically, following the *generalized drive hypothesis* the presence of an audience (or co-actors) should facilitate dominant responses – here, word reading – thus increasing the Stroop interference. Consistent with this prediction, past research have shown that increased arousal enhances the Stroop interference (Conty, Gimmig, Belletier, George, & Huguet, 2010; Pallack, Pittman, Heller, and Munson, 1975; Hochman, 1967).

In contrast, according to the *distraction-conflict hypothesis*, since the presence of others is a source of distraction, participants should narrow their attention on the relevant information – here, color naming – thus reducing the Stroop interference. Consistently with this alternative prediction, previous studies have demonstrated that distraction reduces the Stroop interference (Lavie, 2005; Hartley & Adams, 1974; Houston & Jones, 1967).

The results of several studies using the social Stroop task have provided converging evidence in favor of the *distraction-conflict hypothesis* (Muller & Butera, 2007; Dumas, Huguet & Ayme, 2005; Huguet, Dumas, & Monteil, 2004; Muller, Atzeni, & Butera, 2004; Huguet, Galvaing, Monteil, & Dumas, 1999; MacKinnon, Geiselman, and Woodward, 1985). For example, in the study of Huguet et al. (1999), participants were required to execute a manual version of the Stroop task first alone and then in presence of a confederate. The presence of the confederate was motivated as due to technical problems in another room wherein a different experiment was taking place. In line with the *distraction-conflict hypothesis*, results showed that the Stroop interference was significantly reduced when participants performed the task in presence of an audience, compared to when they executed the task in isolation. The same pattern of results was observed in a second experiment aimed at investigating social facilitation effects in a co-action context implying social comparison. After completing the Stroop task alone, participants performed the task in the presence of a same-sex confederate who worked simultaneously on the identical task. Participants were forced to compare their performance with that of the confederate who, depending on the experimental condition, was either similar (lateral social comparison), slower (downward social comparison), or faster (upward social comparison) than the participant. The authors observed a significant reduction of the Stroop interference in the conditions in which participants faced with a similar or a faster responding co-actor, compared to the conditions in which participants performed the task either alone or in presence of a slower co-actor. On the basis of these results, Huguet et al. concluded that the attentional focus on the relevant information (i.e., the ink color) is not simply due to the fact that social presence induces distraction, but it also results from the participants' willingness to actively inhibit word reading when the co-actor is a relevant target of comparison, that is, when they faced with an actual (in the case of upwards social comparison) or potentially (in the case of lateral social comparison; i.e., mere co-action) self-threatening co-actor (see Muller & Bureta, 2007, and Muller, Atzeni, and Butera, 2004 for similar results and conclusions using a different paradigm). In contrast, when participants' performance is better than that of the co-actor (in the case of downward social comparison), comparison is not relevant and, thus, it is not distracting[3] just because participants are not threatened in their self-evaluation. This interpretation would also explain why co-action effects are not observed when the co-actor works on a different task (Sanders, Baron, & Moore, 1978). In this case, indeed, the co-actor's performance does not represent a self-evaluation threat given that the risk of being inferior to him/her can be easily justified by the fact that s/he is performing a different task.

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[3] A similar interpretation was proposed by Muller & Bureta (2007) and Muller et al. (2004) who demonstrated that self-evaluation threat increases attentional focusing, thus reducing the number of illusory conjunctions in a visual search task.

In a follow-up study, Huguet et al. (2004) provided further evidence that social comparison plays a crucial role in reducing the size of the Stroop interference. Moreover, they demonstrated that attentional control under social comparison is effective when it is unconscious (i.e., when participants competed against the co-actor), whereas this control is ineffective when it is conscious (i.e., when participants performed the task in the perspective of a desired reward). Furthermore, a later study showed that self-evaluation threat is sufficient to reduce the Stroop interference even when the co-actor is not physically present or when participants are required to compare their performance with that of a mentally represented peer group (Dumas et al., 2005; see also Muller & Butera, 2007 for similar results using a different paradigm)[4].

Recently, Sharma, Booth, Brown and Huguet (2010) provided strong evidence that social facilitation is caused by distractor inhibition (i.e., word reading inhibition). In contrast with the traditional *distraction-conflict hypothesis* (Baron et al., 1978), which assumes that social presence reduces the likelihood of processing distractors ("early selection" account), these authors demonstrated that distractors are normally processed, and then strongly inhibited before selecting the correct response ("late selection" account). Sharma et al. implemented an experimental design similar to that employed by Huguet et al. (1999, Experiment 1): Participants performed the manual version of the Stroop task either alone or in (supposedly incidental) presence of a same-sex

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[4] Consistently, Feinberg and Aiello (2006) demonstrated that the physical presence of others is not necessary to produce social facilitation effects (see also Aiello & Svec, 1993). Moreover, Park and Catrambone (2007) showed that social facilitation can also be induced by virtual humans (i.e., a human face presented on the monitor while participants perform the task). In these studies, however, social facilitation effects are attributed to evaluation-apprehension factors (see Zajonc, 1965; Cottrell et al., 1968).

confederate. In contrast with the previous studies, however, they manipulated the interval between successive stimuli (short vs. long) before they examined the RTs distribution (see delta-plot method developed by Ridderinkhof, van den Wildenberg, Wijnen, & Burle, 2004). Consistently with previous findings showing that inhibition requires time to build up (Eimer, 1999; Eimer & Schlaghecken, 1998; Ridderinkhof et al., 2004), Sharma et al. observed that the reduction of the Stroop interference under social presence occurred only when the interval between successive stimuli was long enough to allow participants to inhibit word reading. Conversely, no social facilitation was observed when the interval between successive stimuli was so short to reduce cognitive control processes.

On the basis of these results they proposed that social facilitation effects strongly depend on inhibition processes that can be affected online by the presence of other people.

1.1.2 Conclusive remarks

The practical implications of all these findings are quite obvious. As a whole, social facilitation research, besides providing strong demonstration that the presence of others can have an impact on individual performance, can explain why social presence sometimes facilitates performance and sometimes impairs it.

Despite of the large number of theories on this topic, nowadays most social psychologists agree that, considering the variety of activities that we perform in public, it is unlikely that social facilitation effects can be exhaustively explained by a single mechanism. On the contrary, it is very likely that social facilitation is the result of the converging effects of different factors such as increased arousal, distraction and awareness of evaluation. Furthermore, it makes sense to assume that social facilitation effects can be modulated also by the kind of audience that people are faced with.

Recently, Flynn and Amanatullah (2012) examined whether specific characteristics of co-actors can affect participants' performance as well. Their findings demonstrated that performance gains when participants work nearby high-status co-actors but only if the co-action is independent. According to the authors, high-status individuals have strong influence over peers and can provide a source of inspiration, thus allowing people to elevate their performance. This source of inspiration, however, turns into intimidation when the co-action context is competitive.

1.2 JOINT ACTION

Only recently researchers have started to investigate the cognitive and neural mechanisms underlying joint actions. Joint action can be defined as "…any form of social interaction whereby two or more individuals coordinate their actions in space and time to bring about a change in the environment" (Sebanz, Bekkering, & Knoblich, 2006, p.70). It is not necessary to emphasize how important this question is given that, in everyday life, we are constantly required to engage in some sort of interactions with other people to achieve common goals.

For this reason, a growing number of studies are trying to establish what determines successful joint actions and the degree to which our actions are influenced by specific actions performed by other individuals. A way to assess this issue is to compare a situation in which two complementary actions are performed by an actor (individual condition) with a situation in which one of the two actions is performed by another person (joint condition). The comparison between the individual and the joint conditions may reveal important information about whether the co-actor's task and his/her response are represented and how these representations influence one's own performance. This is exactly what Sebanz, Knoblich, and Prinz (2003) did when they distributed a Simon compatibility task (Simon & Small, 1969) between two participants (i.e., the joint Simon task). By using this paradigm, Sebanz et al. demonstrated that two participants, each performing half of the task, show the same compatibility effects of single participants performing the whole task (i.e., the joint Simon effect). In the light of this finding Sebanz and colleagues (2006) proposed that successful joint actions critically (but not only) depend on the ability to form shared task representations, which would allow people to integrate their own actions with others actions in a whole action planning.

The seminal study of Sebanz et al. (2003) has given rise to an interesting and substantial line of research aimed at investigating the cognitive processes underlying co-representation and how social relationships between co-actors as well as co-action contexts affect co-representations.

In the next sections I briefly describe the main characteristics of the Simon task, and then I provide a brief overview on the joint Simon effect literature. Before that, however, I present the ideomotor theory, that is, the theoretical framework of human action control that has inspired Sebanz's et al. approach.

1.2.1 The ideomotor theory

The ideomotor theory is a well-known theoretical framework for action control that originated in the 19th century (James, 1890; Lotze, 1852), but started to attract interest only at the end of the '900 (Prinz, 1987; Greenwald, 1970). The basic idea behind the different versions proposed during the years is that perception and action are tightly linked together so that imaging an action or perceiving someone else's action creates a tendency to perform that action (Prinz, 1997). Broadly speaking, ideomotor theories assume that actions are represented in terms of their perceptual consequences. By experiencing different types of actions, a learning mechanism allows humans to integrate the motor pattern of these actions with the cognitive representations of their respective perceptual consequences. Thereby, humans can activate motor patterns associated to specific actions by simply accessing to (or thinking of) the representations of their consequences (for a review see Shin, Proctor, & Capaldi, 2010, and Stock & Stock, 2004).

The most influential ideomotor theory is the so-called theory of event coding (TEC; Hommel, Müsseler, Aschersleben, and Prinz, 2001; for a review see Hommel, 2011, 2009). According to this theory, perceived events (stimuli) and produced events (actions) are represented in the same system and by means of the same codes, so that the cognitive system cannot really distinguish between stimuli and responses. Thus, seeing an event activates the action associated with that event, and performing an action activates the associated perceptual event.

One of the core concepts of TEC framework is that of *event file*. TEC posits that cognitive representations of stimuli and actions are composed of several feature codes, which are bound together into a whole *event file*. According to Hommel et al., every external event, including one's own actions, is stored in an *event file*. Event files are sensorimotor networks of codes representing the features of all perceivable action effects. The activation of one code in a given network automatically spreads activation to all the other codes in the same network. Thus, "…thinking of an action always involves the tendency to generate that action motorically by spreading activation from the effect codes to the associated motor codes" (Hommel 2009, p.520; see also Keysers & Perrett, 2004; Jeannerod & Decety, 1995).

A logical implication of the *event file* concept is that the more features are shared by different events (i.e., the more they are similar or the more they overlap), the more they can be related to, compared with, or confused with each other.

Another important aspect of TEC framework is the assumption that cognitive control is achieved by an "intentional weighting" mechanism, which is supposed to operate offline before actions take place (Hommel et al., 2001; for a review see Memelink & Hommel, *in press*). In a nutshell, the basic idea is that preparing for an action requires a top-down priming of those feature dimensions that are relevant to accomplish the task (e.g., color, shape, position, or other perceptual or semantic stimulus features). As a consequence, all stimulus features that are defined on the selected dimension receive more weight and become more salient, thus having a stronger impact on performance. Since perceived events (stimuli) and action events (responses) are represented using the same feature codes, "…making a particular dimension relevant for perceptual discriminations should automatically induce task relevance of the same dimension in action discriminations" (Memelink & Hommel, *in press*, p 5). It is important to know, however, that although the intentional weighting mechanism fosters the processing of task relevant information it does not prevent the irrelevant information to be processed and to impact performance.

Based on the ideomotor framework, which postulates a close link between perception and action, it is reasonable to assume that specific other-generated actions can selectively affect one's own actions. This rationale is what has inspired research on shared task representations.

1.2.2 The Simon paradigm

1.2.2.1 The basic phenomenon

In a typical Simon task, an imperative stimulus (e.g., a red or green square) is randomly presented on the left or on the right of the screen, and participants are required to press a left or right button depending on a non-spatial attribute of this stimulus (e.g., the color, as in the example of Figure 1.1). The Simon effect (e.g., Simon & Small, 1969) refers to the finding that, even if stimulus location is task irrelevant, participants are usually faster and often more accurate when the position of the stimulus corresponds to the position of the required response (i.e., corresponding trials; e.g., left stimulus — left response; see Figure 1.1, left panels) than when it does not correspond (i.e., non-corresponding trials; e.g., right stimulus — right response; see Figure 1.1, right panels).

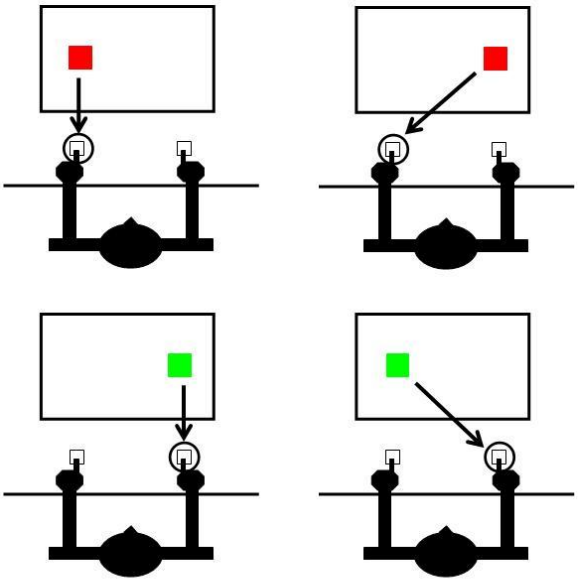

Figure 1.1 Example of a typical Simon task. In each trial a stimulus (a colored square) is presented either on the left or on the right of the screen but its location is irrelevant to the task. Responses are based on the relevant stimulus dimension, which is unrelated to the irrelevant dimension. In the case of this example, the relevant stimulus dimension is the stimulus color and participants have to press the left button when the stimulus is red and the right button when the stimulus is green. Responses are faster when the stimulus location and the response button spatially correspond (left panels) than when they do not correspond (right panels).

Nowadays, all accounts of the Simon effect share the assumption that this effect is due to a competition that occurs, at the response selection stage, between the response spatially corresponding to the stimulus, which is automatically activated when the imperative stimulus is presented (Eimer, 1995; De Jong, Liang, & Lauber, 1994), and the response selected on the basis of the relevant attribute (i.e., dual-route models; Zhang, Zhang, & Kornblum, 1999; Kornblum & Lee, 1995; Zorzi & Umiltà, 1995; De Jong, Liang, & Lauber, 1994; Kornblum, Hasbroucq, & Osman, 1990). According to the dual route models, when the imperative stimulus is presented, it activates the correct response via a controlled (indirect) route, which processes the task-relevant stimulus dimension (e.g., the color) on the basis of the instructions. Simultaneously, the imperative stimulus activates the spatially corresponding response via an uncontrolled (direct) route, which processes the task-irrelevant stimulus dimension (the stimulus location) independently of the instructions. As a result, response selection process is facilitated in corresponding trials in which the irrelevant and the relevant stimulus dimensions activate the same response code, leading to faster reaction times (RTs). Conversely, a conflict takes place in non-corresponding trials in which the irrelevant and the relevant stimulus dimensions activate different response codes, thus slowing down RTs (see Lu & Proctor, 1995, and Umiltà & Nicoletti, 1992, for a review).

1.2.2.1 The Go/NoGo variant of the Simon task

The Simon effect is thought to be an index of the representation of two possible competitive responses. The activation of the representation of two spatially distinct responses, indeed, is the necessary prerequisite for the Simon effect to occur. This assumption is further supported by the fact that the Simon effect does not usually occur in a Go/NoGo version of the task (Ansorge & Wühr, 2004; Callan, Klisz, & Parsons, 1974), in which participants are required to respond to only one stimulus value (e.g., the red color) and to refrain from responding to the other stimulus value (e.g., the green color). Very likely, the absence of the Simon effect in Go/NoGo tasks is due to the fact that when only one response key has to be pressed, this response cannot have any spatial connotation. Indeed, a response can be coded as left (or right) when it is encoded in a context in which there are right (or left) responses. Thus, when only one response is required, even if there are some cues that would allow participants to spatially code their response (e.g., the fact that participants use either the left or right hand, or the fact that they have to use a response device that is either on the left or on the right with respect to another response device), the necessary prerequisite to produce the Simon effect (i.e., the presence of an alternative response) is missing.

Nevertheless, there are several exceptions to this rule (Ansorge & Wühr, 2009, 2004; Hommel, 1996). As an example, the Simon effect arises in Go/NoGo tasks if participants place a passive finger on the alternative response button (Ivanoff & Klein, 2001; Hommel, 1996) or when the Go/NoGo task is preceded by a two-choice task in which participants press both the alternative buttons (Ansorge & Wühr, 2009, 2004).

The response-discrimination hypothesis proposed by Ansorge and Wühr (2004; see also Ansorge & Wühr, 2009) can account for these exceptions. According to Ansorge and Wühr, the Simon effect occurs because participants use the stimulus position to discriminate between different responses that are stored in working memory. In Go/NoGo tasks the stimulus position is not useful to discriminate between responses, given that the two response options are not spatially defined: Participants have to decide whether to respond or to withhold the response. However, if the Go/NoGo task is executed after a two two-choice task, working memory representations of two distinct and spatially-defined responses can be transferred from the first task to the Go/NoGo task. In other words, the to-be discriminated responses activated in the two-choice task and stored in working memory are then transferred and kept active in the subsequent Go/NoGo task, even if only a single response is required. As a consequence, the Simon effect occurs in the Go/NoGo task as well.

1.2.3 The joint Simon paradigm

1.2.3.1 The basic phenomenon

Sebanz et al. (2003) first discovered the phenomenon nowadays known as "joint Simon effect". In their seminal work, Sebanz et al. distributed the Simon task between two individuals, sitting next to each other, in such a way that each person responded to only one of the two possible values of the stimulus by pressing the button in front of him/her, that is, they performed two complementary Go/NoGo task (e.g., one participant responded to the red color only and the other participant responded to the green color

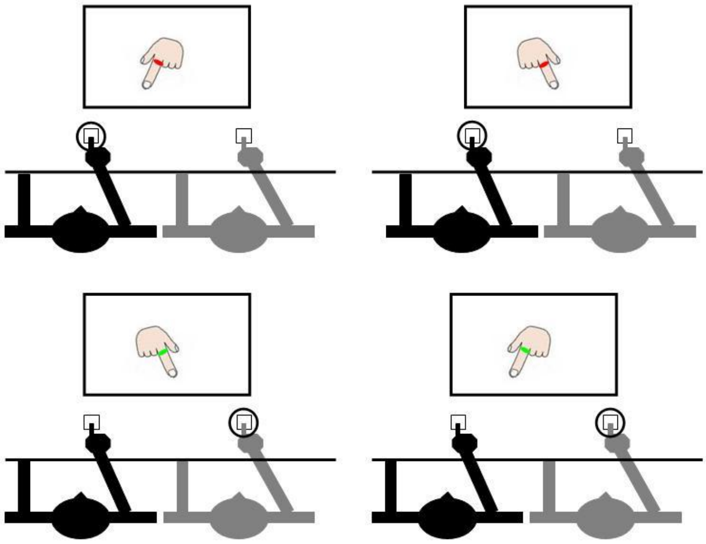

Figure 1.2 Schematic representation of the joint Simon paradigm employed by Sebanz et al. (2003). Two participants sit next to each other with two response buttons placed in front of their body. In each trial a picture of a hand pointing to the left, right or centrally is presented. The direction of the pointing finger is irrelevant to the task. The relevant stimulus attribute is represented by the color of the ring, which can be either red or green. Participants are instructed to perform two complementary Go/NoGo tasks: e.g., The participant sitting on the left has to respond when the ring is red, whereas the participant sitting on the right has to respond when the ring is green. Responses are faster when the direction of the pointing finger corresponds to the position of the responding participant (left panel) than when the direction of the pointing finger corresponds to the position of the other participant (right panel).

only). Targets were presented as colored (i.e., red or green) rings on the picture of an index finger pointing to the left, to the right, or centrally (as in the example of Figure 1.2). In this version of the paradigm, the relevant stimulus attribute was represented by the ring color, whereas the irrelevant stimulus attribute was conveyed by the direction of the pointing finger.

Interestingly, although instructions required each participant to perform a Go/NoGo task, the Simon effect was nevertheless observed: RTs of each participant were faster when the direction of the pointing finger coincided with the position of the participant who was in charge of responding (e.g., leftward pointing finger — left-side participant; see Figure 1.2, left panel) than when the direction of the pointing finger coincided with the position of the co-actor (e.g., rightward pointing finger — left-side participant; see Figure 1.2, right panel). Importantly, the Simon effect was observed neither when participants carried out the Go/NoGo task individually (i.e., without a co-actor) nor when they performed the Go/NoGo task next to a non-actively involved co-actor (i.e., when the co-actor merely sat beside the participant without responding to the complementary color; see also Tsai, Kuo, Hung, & Tzeng, 2006). Based on these findings, Sebanz et al. concluded that responding to the Go stimuli in a joint setting in which another person is responding to the NoGo stimuli is functionally similar to the condition in which a single person takes care of both stimuli/responses (i.e., in two-choice Simon tasks). In analogy with what happens in regular two-choice Simon paradigms, in joint Simon tasks the response spatially corresponding to the task-irrelevant spatial code (i.e., left- vs. right-pointing finger) is automatically activated, even if this response is assigned to another person. As a consequence, a response selection conflict takes place when the irrelevant and the relevant stimulus attributes activate two different responses. Conversely, when participants carry out the Go/NoGo task individually (i.e., without a co-actor performing the complementary task), only the actor‘s response is represented so that no response conflict occurs and, thus, the Simon effect does not show up. Indeed, as previously claimed, the representation of two spatially distinct responses is necessary for the Simon effect to occur.

To account for the joint Simon effect, Sebanz and colleagues proposed that when two individuals perform together two complementary parts of the same task, each actor represents not only his/her own task but also the task of the co-actor and integrates these representations in his/her action planning, the so-called *action co-representation account* (Sebanz, Bekkering, & Knoblich, 2006). The occurrence of the Simon interference effect in the joint but not in the individual Go/NoGo version of the task has been considered a convincing evidence that joint action contexts lead participants to form shared representations of tasks, even if it would be more effective to ignore the co-actor’s task.

The joint Simon effect has been replicated many times (Sebanz, Knoblich, Prinz, & Wascher, 2006; Sebanz, Knoblich, & Prinz, 2005) and it has been obtained also with *abstract* stimuli, like lateralized colored squares (Hommel, Colzato, & van den Wildenberg, 2009; Welsh, Higgins, Ray, & Weeks, 2007; Tsai et al., 2006), and auditory stimuli (Ruys & Aarts, 2010; Vlainic, Liepelt, Colzato, Prinz, & Hommel, 2010; for an extension of the classical paradigm see Ferraro, Iani, Mariani, Nicoletti, Gallese, & Rubichi, 2012; Milanese, Iani, Sebanz, & Rubichi, 2011, and Milanese, Iani, & Rubichi, 2010).

The action co-representation account of the joint Simon effect (Sebanz et al., 2006) relies on the ideomotor theories (Greenwald, 1970; James, 1890; see Section 1.2.1) that, as previously mentioned, postulate a close link (i.e., a common code) between perception and action. According to these theories, imaging to perform an action as well as observing (or knowing about) someone else's action activates the same motor representations that are involved in the execution of that action. These representations lead to a tendency to perform that action, which needs to be suppressed (Prinz, 1997). Consistently with this assumption, event-related potentials (ERPs) recorded during Go/NoGo joint and individual Simon tasks showed that participants exhibit a stronger response inhibition in NoGo trials of the joint task than in those of the individual task (Tsai, Kuo, Hung, & Tzeng, 2008; Sebanz, Knoblich, Prinz, & Wascher, 2006; Tsai et al., 2006; for errors monitoring in joint Go/NoGo tasks see De Bruijn, Miedl, & Bekkering, 2011, and De Bruijn, Miedl, & Bekkering, 2008). In a similar vein, the results observed by Holländer, Hung, and Prinz (2011) suggest that task sharing leads to the activation of the motor system of the non-acting participant when the required response is up to the co-actor. Importantly, they observed that this motor activation was independent on the specific hand used by the co-actor to perform the task, indicating that participants adopted an egocentric perspective in simulating the co-actor's action.

1.2.3.2 Impact of contextual and social factors on the joint Simon effect

Since Sebanz's et al. seminal work (2003), several other studies have been conducted to investigate the mechanisms underlying the joint Simon effect. A main issue has been the identification of the conditions that allow others' actions to be represented and included in one's own action plan.

Some of these studies suggest that participants can co-represent the co-actor's action also when the visual and auditory feedback from these actions is hampered (Vlainic et al, 2010; Sebanz et al., 2003) and even if the co-actor performs the task in a different room (Ruys & Aarts, 2010; Tsai et al., 2008).

For instance Vlainic at al. (2010), by employing an auditory version of the joint Simon task, observed the joint Simon effect with participants wearing opaque goggles, which prevented them from observing the co-actor's action, and responding by using a noise-free keyboard, which did not provide any auditory feedback about the co-actor's action. Consistently, Tsai et al. (2008) and Ruys and Aarts (2010) observed that the mere belief of co-acting with another person, who was thought to perform the complementary Go/NoGo task in a different room, was sufficient to induce the joint Simon effect (but see Welsh et al., 2007, for contrasting results).

Even participants' mood was found to modulate the joint Simon effect (Kuhbandner, Pekrun, & Maier, 2010). In the study of Kuhbandner et al., participants performed the joint Simon task after seeing a neutral or an emotionally-charged movie presented for inducing a neutral, positive or negative mood. The results showed that, compared to the neutral mood condition, negative mood significantly reduced the Simon effect, whereas positive mood significantly enhanced the joint Simon effect. To account for their results, Kuhbandner et al. proposed that mood can modulate the tendency to take each other's tasks into account, either by enhancing this tendency (positive mood) or by decreasing this tendency (negative mood; see Hommel, 2012).

Finally, other studies have provided converging evidence showing that the others' actions can be incorporated into one's own task representation only when the co-actor is perceived as an intentional agent. Indeed, joint action effects were not observed when participants were required to share the task with a puppet (Tsai & Brass, 2007; but see Stenzel et al., 2012 and Muller et al., 2011a), a computer (Tsai et al., 2008), or a human co-actor whose responses were controlled mechanically (Atmaca et al., 2011).

A related line of research has examined whether the joint Simon effect can be modulated by social factors, such as the kind of relationship between the actor and the co-actor (Hommel et al., 2009), the cooperative or competitive nature of the interaction (Iani et al., 2011; Ruys & Aarts, 2010), and the group membership (Müller, Kühn, et al., 2011b; Iani, Anelli, Nicoletti, Arcuri, & Rubichi, 2011). For example, Hommel et al. (2009) showed that the occurrence of the joint Simon effect depends on the valence of the relationship that is established between the two interacting participants. Specifically, they observed a joint Simon effect when the co-actor behaved friendly (positive relationship) but not when the co-actor acted unfriendly (negative relationship).

In the same vein, Iani et al. (2011) demonstrated that competition may prevent participants from taking into account the co-actor's task. They observed no joint Simon effect when the two interacting participants were required to compete to receive an economic reward on the basis of their speed and accuracy (but see Ruys & Aarts, 2010).

Finally, a recent study of Müller, et al. (2011b) provided evidence supporting the idea that even mere group membership can modulate the degree to which others' actions are represented. They observed a joint Simon effect when participants were required to share the task with an in-group member (i.e, an image of a white hand), but not when they share the task with an out-group member (i.e., an image of a black hand).

1.2.3.3 What is really co-represented in joint Simon task?

Another important question pertains to what is really co-represented in joint Simon tasks. In a follow-up study, Sebanz and colleagues (2005) provided evidence suggesting that co-representations are not restricted to the partner's actions but comprise also the conditions under which these actions have to be performed (see Kiernan, Ray, & Welsh, 2012 for consistent results demonstrating that even the effects of the co-actor's actions and his/her intentions can be represented). In this study, participants in a pair were asked to take care each of one of two different attributes of the same target stimulus: One participant had to respond only to one of two possible stimulus colors and the other participant had to respond only to one of two possible pointing directions. In half of the trials responses of the actor and the co-actor overlapped in time (double response), whereas in the other half the actor and the co-actor took turns in responding (single response). Results showed a significant slowing down in RTs in double response trials as compared to single response trials, thus demonstrating that the performance of each participant was influenced by the partner's task. To account for this finding, Sebanz et al. proposed that the impairment of performance in double response trials is the result of an increased response conflict produced by the simultaneous activation of two different task rules.

Recently, Wenke, Atmaca, Holländer, Liepelt, Baess, and Prinz (2011), after reviewing the literature on the joint Simon effect, suggested that the joint Simon effect might also be induced by others source of interference, such as the conflict that might arise when self-other discrimination is required. According to the authors, the joint Simon effect observed in most of the previous studies can be accounted for by assuming that participants co-represent that another person is responsible for the complementary part of the task and when it is his/her turn of responding. This can lead to an agent identification conflict when some aspects of the task (e.g., stimulus position) prime the co-actor's turn (the *actor co-representation account*; for consistent results see Liepelt, Wenke, & Fischer, 2012; Ferraro, Iani, Mariani, Milanese, & Rubichi, 2011; Liepelt, Wenke, Fischer, & Prinz, 2011; Philipp & Prinz, 2010; but see Welsh, 2009).

The assumption that the joint Simon effect reflects action/task co-representations has been recently called into question by other authors according to whom performing a Go/NoGo Simon task in close proximity to another person simply re-introduce the possibility to code spatially two alternative responses (Dolk, Hommel, Prinz, & Liepelt, 2013; Dittrich, Rothe, & Klauer, 2012; Dolk, Hommel, Colzato, Schütz-Bosbach, Prinz & Liepelt, 2011; Guagnano, Rusconi, & Umiltà, 2010). Hence, given that spatial response coding is sufficient for the Simon effect to occur in individual Go/NoGo tasks (cf. Ansorge & Wühr, 2009, 2004), it makes sense to assume that the spatial coding of actor and co-actor positions is sufficient to induce the joint Simon effect as well.

1.2.3.4 The referential coding account of the joint Simon effect

The results of recent studies have raised some doubts about the social nature of the joint Simon effect. Indeed, some authors have advanced the hypothesis that this effect may be mainly a spatial phenomenon, induced by the spatial coding of participants' response position with reference to the sitting position of the co-actor. This would reintroduce a dimensional overlap between the task-irrelevant stimulus dimension and the response dimension, which is usually missing in individual Go/NoGo Simon tasks.

The first evidence in favor of this non-social explanation of the joint Simon effect comes from a study of Guagnano, Rusconi, and Umiltà (2010). In this study, participants in a pair were required to execute two independent detection tasks: One participant had to respond only to red stimuli and the other participant had to respond only to blue stimuli. The majority of the trials involved the simultaneous presentation of the red and blue targets, one on the left and one on the right of the screen, thus eliminating the turn-taking aspect that characterized typical joint Simon tasks. Co-acting participants performed this task sitting either close to or further apart from each other. A Simon effect was observed although the tasks of the actor and the co-actor were independent from one another (i.e., the actor and the co-actor did not share any goal). More importantly, the Simon effect was present only in the condition in which the actor acted in close proximity as compared to the condition in which the co-actor sat far from the actor[5]. Based on these results, Guagnano et al. proposed that the presence of another person performing a task in the peripersonal space of the participant provides him/her with a reference to spatially code his/her own response. The spatial coding of the response position of the participant is sufficient to give rise to the Simon effect by facilitating participant's responses in corresponding trials (but see Ferraro et al., 2011

[5] Recently, Welsh, Kiernan, Ray, Pratt, Potruff, and Weeks (2013a) failed to replicate this finding. In their study, participants were required to execute two independent detection tasks while sitting outside of each other's peripersonal space. In contrast to Guagnano et al., the authors observed a significant Simon effect in this condition (see Guagnano, Rusconi, & Umiltà, 2013, and Welsh et al, 2013b for a discussion).

for results showing that the joint Simon effect is mainly due to interference in non-corresponding trials rather than to facilitation in corresponding trials).

In the same vein, a recent study of Dolk et al. (2011) questioned the action co-representation account. In this study, participants performed the auditory version of the joint Simon task while their sense of ownership over the co-actor's hand was experimentally induced through the so-called rubber hand illusion (RHI, Botvinck & Cohen, 1998). The RHI is the phenomenon for which seeing a rubber (or another person) hand synchronously stroked with one's own hidden hand produces the illusion that the seen rubber hand is part of one's own body. The RHI illusion does not occur when the rubber and the participant hands are stroked asynchronously.

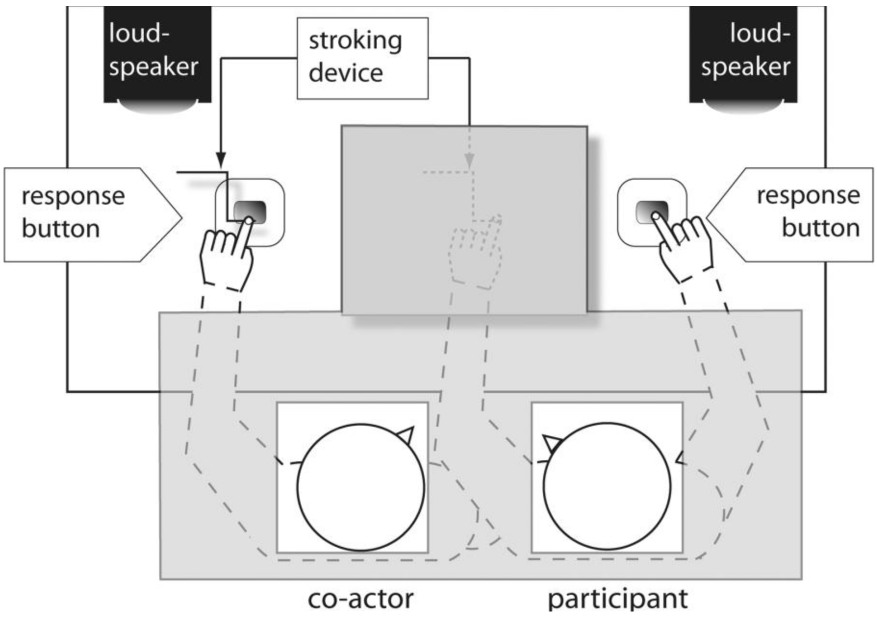

Figure 1.3 Experimental setting in Dolk et al. (2011). In each trial one of two sounds was delivered from either the left or the right loudspeaker. Participants performed two complementary Go/NoGo task: One participant was instructed to respond only to one sound, and the other participant had to respond only to the other sound. During the Go/NoGo task, left hands of both the actor and the co-actor were mechanically stroked, either synchronously or asynchronously, so as to induce or not the RHI.

Dolk et al. used this manipulation to test the assumption that the joint Simon effect reflects the integration of the co-actor's action into the actor's task representation. The participant sat on the right and was required to respond to one of two sounds by pressing the button in front of him/her with the right hand (see Figure 1.3). The co-actor sat on the left and responded to the complementary sounds by pressing with the left hand the button in front of him/her.

During the task, the left hand of the participant was hidden and stroked either synchronously or asynchronously with the left hand of the co-actor, thus to induce or not in the actor the illusion of ownership over the co-actor's hand. According to the authors, inasmuch as the joint Simon effect is due to the integration of the co-actor's action in one's own action planning, this should result into a larger effect in the synchronous stroking condition than in the asynchronous stroking condition. Yet, the opposite pattern occurred: The asynchronous stroking condition gave rise to a larger joint Simon effect as compared to the synchronous stroking condition. Hence, Dolk et al. proposed that the joint Simon effect is not due to the integration of the co-actor's action but rather to the separate perception of one's own action from the co-actor's action. Based on this finding and inspired by TEC framework (Hommel et al., 2001; Hommel, 2013; Prinz, 1997; see also Section 1.2.1), Dolk et al. advanced the so-called *referential coding account* of the joint Simon effect (see also Dolk et al., 2013; Dittrich et al., 2012; Hommel, 1993). According to the *referential coding account*, given that self-generated and (perceived) other-generated actions are represented by their sensory consequences, the presence of another individual sitting next to the participant and performing the task can be considered as just another (salient) event which, being it similar to the actor's action event, provides him/her with an alternative action. The presence of an alternative action requires the participant to discriminate between representations referring to his/her action and others concurrently activated representations (cf. Ansorge & Wühr, 2004; see also *response-discrimination account* in Section 1.2.2.1). Proper discriminations can be achieved by spatial coding one's own response position with reference to such alternative events. This, in turn, leads to a match or a mismatch between stimulus and response sets, which gives rise to the Simon effect (Kornblum et al., 1999).

In a follow-up study, Dolk et al. (2013) demonstrated that any sufficiently salient event, not necessary another person, can represent an action alternative to that of the participant, thus enabling the spatial coding of the participant's response position. Indeed, they observed a Simon effect in different experiments requiring participants to execute individually an auditory Go/NoGo Simon task while different salient events (i.e., a Japanese waving cat, a clock, or a ticking metronome) occurred on the side opposite to the participant's response position.

In line with the *referential coding account* and with the results reported by Dolk et al. (2011, 2013), Dittrich et al. (2012) proposed that the joint Simon effect occurs because the spatial arrangement of the two co-acting participants (left vs. right) emphasizes the horizontal dimension of the response, which can match or not with the spatial horizontal dimension of the stimulus. Consistently, Dittrich et al. did not observe a joint Simon effect in the condition in which two co-acting participants, sitting side-by-side, were required to perform a Go/NoGo task in which both target stimuli and responses were arranged along a vertical dimension. According to the authors, the absence of the Simon effect could be accounted for by assuming that the sitting position of the participants made participants to code their responses as “left” and “right” instead of coding them as “up” and “down”. As a consequence, the spatial dimension of the responses did not match anymore with the spatial dimension of the stimuli and the Simon effect did not show up.

1.2.3 Other joint Simon-like paradigms

The occurrence of an interference effect in joint tasks was recently replicated by splitting other Simon-like paradigms in two complementary Go/NoGo tasks, performed by two participants sitting side-by-side. For instance, Atmaca, Sebanz, Prinz, & Knoblich (2008) distributed between two participants a parity judgment task. This task usually requires classifying a centrally presented number (ranging from 1 to 9) as either odd or even, by pressing a left or right button. Typically, even though number magnitude is irrelevant to perform the task, left responses are faster for numerically small numbers, whereas right responses are faster for numerically large numbers, a well-known phenomenon called SNARC effect (i.e., *Spatial Numerical Association of Response Codes*; Dehaene, 1997; Dehaene, Bossini, Giraux, 1993). This effect is thought to be due to the fact that numbers are spatially represented on a mental number line, which is oriented from left to right. The SNARC effect is usually attributed to the automatic activation of spatial representations of number magnitudes, which interact with response position codes. In the joint version employed by Atmaca et al., one participant had to respond only to odd numbers and the other participant had to respond only to even numbers. Results showed that participants sitting on the left reacted faster to small than large numbers, whereas participants sitting on the right were faster in responding to large than small numbers. In contrast, in the individual Go/NoGo task no SNARC effect occurred. Consistently with the interpretation advanced to explained the joint Simon effect, the occurrence of the SNARC effect in the joint but not in the individual Go/NoGo task seems to suggest that participants activated the representation of the co-actor's action alongside to the representation of their own action, thus giving rise to the same conflict between responses that occurs when left and right responses are emitted by a single individual. According to Atmaca et al. the occurrence of the joint SNARC effect demonstrates that the close link between perception and action can have an impact on the processing of symbolic information as well.

In a further study, Atmaca, Sebanz, and Knoblich (2011) demonstrated that action co-representations can also occur when the task involves arbitrary stimulus-response associations. In this study, a flanker task (Eriksen & Eriksen, 1974) was distributed between two participants sat alongside each other. Participants in a pair were presented with a string of letters and were instructed to press the button in front of their body depending on the identity of the central (target) letter. One participant had to respond only when the target was H or K, and the other participant had to respond only when the target was C or S. Target letters were flanked on both the left and right sides by distracter letters that could be the same as the target (identical trials; e.g., KKKKK), assigned to the same participant (congruent trials; e.g., HHKHH), assigned to the co-actor (incongruent trials; e.g., SSKSS), or associated to none response (neutral trials; e.g., UUKUU). The flanker effect refers to the finding that RTs are usually faster when flankers are the same as the target (identical trials) or when they are associated to the same response (congruent trials), as compared to the condition in which they require a different response (incongruent trials). This effect is thought to reflect the fact that both the target and the flankers activate the responses associated with them on the basis of the task instructions. As a consequence, performance is facilitated when the target and the flankers activate the same response, whereas a conflict takes place when they activate different responses (see Cohen & Shoup, 1997; Sanders & Lamers, 2002, for reviews). Consistently, Atmaca et al. observed that RTs of each participant were slower when the target was flanked by letters that would have required a response from the co-actor (incongruent trials). The flanker effect occurred also when participants performed the same Go/NoGo flanker task individually. However, the effect was significantly larger in the joint than in the individual Go/NoGo task.

Interestingly, the joint flanker effect was not observed when participants performed the joint task with co-actor whose responses were controlled by an electromagnet, which pulled down the co-actor's finger when it was his/her turn of responding. This finding would demonstrate that for action co-representation to be formed the co-actor has to be perceived as an agent acting intentionally.

Finally, other studies demonstrated that participants performance in joint tasks can also be influenced by the co-actor's focus of attention (the social Navon effect; Bockler, Knoblich, & Sebanz, 2012), and by inhibition processes related to the co-actor's action (the social inhibition of return; Cole, Skarratt, & Billing, 2012; Welsh et al., 2005, and the social spatial negative priming; Welsh & McDougall, 2012).

1.2.4 Conclusive remarks

After Sebanz's et al. (2003) seminal study, the literature on the joint Simon effect has grown very quickly. Despite of the different interpretations that have been advanced to account for this effect, most of the authors agree that the joint Simon task is a useful tool to investigate the degree of interpersonal integration. Indeed, the size of the joint Simon effect has been found to change as a function of the religious practice (Colzato, Zech, Hommel, Verdonschot, van den Wildenberg & Hsieh, 2012), the social self-construal (Colzato, De Bruijn, & Hommel, 2012) and the cognitive style of thinking (Colzato, van den Wildenberg, & Hommel, in press). Furthermore, the joint Simon paradigm seems to be useful to evaluate whether and to what extent self-other integration can be achieved by clinical samples, such as, individuals with autism (Sebanz, Knoblich, & Stumpf, 2005), brain damaged patients (Humphreys & Bedford, 2011), schizophrenic patients (Liepelt, Schneider, et al., 2012) and congenitally-blind individuals (Dolk, Liepelt, Prinz, & Fiehler, 2013).

2

Aims of the study

Recent years have witnessed an increasing overlap between cognitive psychology and social psychology. Given that humans are social beings and that the study of human behavior cannot prescind from the social context in which it occurs (see Cacioppo, Berntson, Lorig, Norris, Rickett, & Nusbaum, 2003), recent studies have started to investigate whether, and to what extent, performing a task with (or in presence of) another person may change individual performance.

Interference paradigms are particularly suitable for addressing this issue. The rationale is that most of them can be split in two (complementary or different) parts which, in turn, can be distributed between two different individuals. By comparing task performance when participants act in the joint context and when they perform the task individually, important information may be obtained about whether the co-actor's task is represented and how this representation influences one's own performance.

The joint Simon task, developed by Sebanz et al (2003), is nowadays one of the most widely-used paradigms to address this issue (see Section 1.2.3).

In the standard version of the Simon task, a single person is required to emit left or right responses depending on the color (e.g., red and green) of a target stimulus that randomly appears on the left or right side of the screen. The Simon effect refers to the finding that

RTs are usually faster and more accurate when the target position corresponds to the position of the required response than when it does not correspond (Simon & Small, 1969). The presence of such an effect demonstrates that, although the target position is irrelevant to perform the task, it is automatically processed and it interferes with responses, giving rise to a conflict between responses when the target appears on the opposite side of the required response (Kornblum & Lee, 1995; De Jong, Liang, & Lauber, 1994; Kornblum, Hasbroucq, & Osman, 1990; for a review see Lu & Proctor, 1995).

Sebanz et al. (2003) showed that the Simon effect occurs also in the joint version of the task – namely the joint Simon effect – in which the two action alternatives (the left and right responses associated respectively to the two stimulus colors) are distributed between two participants, sitting next to each other, so that each participant performs a Go/NoGo Simon task (e.g., the left-side participant responds to the green stimuli only and the right-side participant responds to the red stimuli only). Apparently it would be nothing surprising about this effect, were it not for the fact that no Simon effect usually occurs when participants perform the Go/NoGo Simon task individually, without a co-actor (Ansorge & Wühr, 2009, 2004; Sebanz et al, 2003).

As Sebanz et al. (2003) stated, the presence of the Simon interference effect in joint but not in individual Go/NoGo tasks is hard to explain in terms of social facilitation (Zajonc, 1965; Baron et al., 1978, see Section 1.1), given that studies belonging to this area have observed the same pattern of results regardless of whether participants performed the task simply in presence of others or with another person engaged in the same actions: Typically, performance is facilitated on easy tasks and it is impaired on difficult tasks (Aiello & Douthitt, 2001; Guerin, 1993).Thus, social facilitation effects do not seem to depend on the specific actions carry out by other people. Rather, the joint Simon effect can be better accounted for within the framework of ideomotor theories which, assuming a close link between perception and action, postulate that perceiving (or imaging) actions made by others is functionally similar to perform the same actions (Prinz, 1997; Hommel et al., 2001; see Section 1.2.1). Consistently with ideomotor theories, Sebanz et al. proposed the so-called *action co-representation account* (Sebanz, Bekkering, & Knoblich, 2006; Knoblich & Sebanz, 2006). Following this account, the joint Simon effect occurs because participants represent (and incorporate in their task representation) the action to be executed by the co-actor, thus giving rise to the same conflict between actions that arises when they take care of both left and right responses (for a different interpretation see Dolk et al., 2013; Dittrich et al., 2012; Dolk et al., 2011; Guagnano et al., 2010; see also Section 1.2.3.4 and later in this chapter).

The interference effect was replicated by splitting other Simon-like paradigms in two complementary Go/NoGo tasks, performed by two participants sitting side-by-side: the joint SNARC effect (Atmaca et al., 2008) and the joint flanker effect (Atmaca et al., 2011; see Section 1.2.3). For instance, in the study of Atmaca et al. (2008) participants were required to respond to either odd or even centrally-presented numbers, ranging from 1 to 9, by pressing the button in front of their body. Participants performed this task both individually and with a co-actor who was in charge of the complementary task (e.g., if the participant responded to odd numbers then the co-actor reacted to even numbers). Typically, when a single participant performs the whole parity task individually, by pressing the left and right button, a stable finding is that left responses are faster for small than large numbers, whereas right responses are faster for large then small numbers. This effect, known as SNARC effect, has been accounted for by assuming that numbers are represented in succession along a left-to-right spatially oriented line. The spatial information, conveyed by number magnitude, automatically interacts with response selection processes, thus slowing down RTs in spatially non-corresponding trials (e.g., small number – right response; Dehaene, 1997; Dehaene et al., 1993). Consistently, Atmaca et al. observed that in the joint SNARC task, participants sitting on the left reacted faster to small than large numbers, whereas participants sitting on the right were faster in responding to large than small numbers, thus resembling the same pattern of results that occurs when a single participant performs the whole task individually. In contrast, in the individual Go/NoGo task, participants' RTs were similar for both small and large numbers. According to the authors, the occurrence of the SNARC effect in the joint but not in the individual Go/NoGo task suggests that, similarly to what happens in joint Simon tasks, participants represented the co-actor's response alongside to their own response.

In a follow-up study, Atmaca et al. (2011) extended these findings suggesting that action co-representation can also occur when the task involves arbitrary stimulus-response associations. In this study, the authors employed the joint version on another well-known interference task, that is, the flanker task (Eriksen & Eriksen, 1974). Typically, this task requires participants to judge, by pressing one of two response buttons, the identity of a central target letter, flanked on both sides by distracter letters. The flanker effect refers to the fact that participants are usually faster when flankers are the same as the target (identical trials) or when they are associated to the same response (congruent trials), as compared to the condition in which they require a different response (incongruent trials). Atmaca et al. divided the flanker task in two complementary Go/NoGo tasks, which required each participant to respond to two of four different target letters. Participants worked on this Go/NoGo task both individually and with a partner who responded to the others two target letters. Results showed that, in the joint task, participants were significantly slower when the target letter was flanked by letters that would have required a response from the co-actor. Importantly, the flanker effect occurred also in the individual task but was significantly smaller as compared to the effect in the joint task.

Taken together, all these studies demonstrate that when two participants share an interference paradigm in such a way that each of them is responsible for complementary parts of the task, they show interference effects that do not usually occur (or are strongly reduced) when the same task is performed by each participant alone. As previously said, all these joint effects were accounted for by assuming that, in joint tasks, participants represent also the co-actor's action and include this representation in their own action planning. As a consequence, interference effects occur when a stimulus feature creates a conflict between self- and other-generated responses, similar to the response conflict that arises among two self-generated responses (for a review see Knoblich et al., 2011).

If this is true, namely, if knowing about the co-actor's task leads automatically to activate the representation of his/her response and to integrate it in one's own action planning, one would expect to observe interference effects not only when the actor and the co-actor perform two complementary parts of the same task, but also when they are responsible for different parts of the same task. The results of a follow-up study of Sebanz et al. (2005) appear consistent with this expectation. In this study, two interacting participants were required to respond to two different dimensions of the same stimulus. One participant responded to only one of the two possible stimulus colors, whereas the other participant responded to only one of the two possible stimulus positions. Results showed that RTs were significantly slower on trials that required a response from both participants compared to trials that required a response from participants in turn. On the basis of this finding, Sebanz et al. concluded that each actor co-represent the co-actor's task to such an extent that performance can deteriorate when the two tasks require a response from both actors simultaneously. However, the results of a recent study of Heed, Habets, Sebanz, and Knoblich (2010) challenge this interpretation. Indeed, Heed et al. demonstrated that sharing an interference paradigm with a co-actor, concurrently responsible for a different part of the task, may lead to a facilitation effect instead of producing interference. In this study, participants performed a visual-tactile interference task in which they were required to judge the location of a tactile stimulus (top vs. bottom) while ignoring a visual distractor (a light) that could be either spatially-congruent or -incongruent with the target location (e.g., touch at the top and light at the top vs. touch at the top and light at the bottom). Participants performed the task both alone and with a partner who responded to the visual distractors. Results showed that the joint setting significantly reduced the crossmodal interference effect (slower RTs for spatially-incongruent trials; Spence, Pavani, & Driver, 2004), which typically occurs when the task is performed individually. Importantly, the reduction of the crossmodal interference effect was observed neither when the co-actor performed his/her part of the task sitting far from the participant (in the extrapersonal space; but see Teneggi, Canzoneri, di Pellegrino, & Serino, 2013) nor when the co-actor responded only to a subset of visual distractors (e.g., when the co-actor responded to red lights only and not to green lights).

The finding that the crossmodal interference effect was reduced in the joint condition seems to be at odds with the action co-representation account (Sebanz et al., 2006). Indeed, following this account, and on the basis of earlier findings on shared task representations, the crossmodal interference effect should have been larger in the joint than in the individual condition, given that the co-actor's task (i.e., to respond to the position of the irrelevant lights) is supposed to be automatically represented and, as such, the interference effect produced by the irrelevant lights should have been larger.

To account for the reduced crossmodal interference effect observed in their social condition, Heed et al. (2010) proposed that sharing a crossmodal interference paradigm with a partner acting upon stimuli from a different sensory modality can modulate the crossmodal integration by reducing the influence of the distractor stimuli: Knowing that the co-actor is taking care of visual stimuli allows participants to ignore them in incongruent trials. According to Knoblich et al. (2011) the results observed by Heed et al. are not at odds with the action co-representation account (Sebanz et al., 2006) but they simply demonstrate that "representing the other's task could also facilitate task performance given that, unlike in previous studies, stimuli from two different sensory modalities were distributed between two co-actors" (Knoblich et al., 2011, pp. 79-80). Thus, following this hypothesis, the results observed by Heed et al. could be strictly related to the crossmodal nature of the stimuli, that is, to the fact that stimuli belonging to two different sensory modalities were distributed between the two participants.

However, an alternative explanation can be advanced. The different nature of the tasks can account for these contrasting results. In the social version of the Simon and others Simon-like paradigms participants perform a Go/NoGo task requiring them to take turns in responding to two different values of the same target stimulus. The fact that participants have to pay attention to the same target stimuli as their respective co-actors could inevitably induce them to take into consideration the co-actor's task and to activate the alternative (and complementary) response associated to this task, thus producing interference. Note that the same rationale can be applied to the results observed by Sebanz's et al. (2005). In this case, indeed, although the actor and the co-actor were engaged in two different tasks, after all they were required to pay attention to the same target stimuli.

Conversely, in the paradigm adopted by Heed et al. (2010), the two participants executed two independent and simultaneous tasks, which required them to take care of two different stimuli. Thus, the fact that another person is concurrently taking care of the distractor stimuli could allow participants to succeed in ignoring them.

Based on this alternative interpretation, one can assume that task sharing produces different effects depending on the nature of the task: It gives rise to interference when participants have to perform two complementary Go/NoGo tasks, thus working on two different values of the same stimulus; whereas it determines a reduction of the interference when they have to execute simultaneously two independent tasks, thus working on two different stimuli. If this were true, the same finding of Heed et al.

(2010) should be found also when participants perform together and simultaneously two independent tasks involving stimuli of the same sensory modality.

The first study of this thesis aims at testing this hypothesis. Study 1 (Chapter 3) comprises three experiments in which I employed the joint version of the picture-word interference (PWI) paradigm, which requires participants to name a target picture while ignoring a distractor word printed on it **(**Rosinski, Golinko, & Kukish, 1975; see Section 3.1 for a more detailed description of this paradigm). The typical finding is that, despite the instructions to ignore the word, participants cannot refrain from reading and processing the distractor words, and this leads to a performance impairment (i.e., slower RTs) when the names of the picture and the written word belong to the same semantic category: A phenomenon called semantic interference effect (Rosinski et al., 1975). Noticeably, the PWI task can be spit in two different tasks, that is, to name the picture and to read the word, which can be concurrently carried out by two different participants, thus making the typical PWI task a joint task. Importantly, in contrast with the paradigm adopted by Heed et al. (2010), wherein the participants were presented with two stimuli of different sensory modalities, in the PWI paradigm the two stimuli (the picture and the word) share the same (visual) modality. The implementation of the joint version of the PWI, thus, seems particularly suitable to rule out the interpretation advanced by Knoblich et al. (2011) and to verify the alternative hypothesis I advanced according to which the different effects in joint tasks depend on the different nature of the tasks. Specifically, if my interpretation of the effects observed in joint paradigms is correct, then sharing a PWI paradigm with a co-actor concurrently responsible for the task irrelevant information should allow participants to ignore the this information, thus reducing the semantic interference effect.

In Study 2 (Chapter 4), instead, I employed the joint version of the Simon task (Sebanz et al., 2003) to shed light on the ongoing and quite lively debate about the real nature of the joint Simon effect. Indeed, as discussed in Chapter 1 (Section 1.2.3.4), the assumption that the joint Simon task is an index of action co-representation has been recently challenged by the results of other studies that appear to demonstrate that this effect simply reflect an instance of spatial coding that occurs independently of the task performed by the co-actor (Dolk et al., 2013; Dittrich et al., 2012; Dolk et al., 2011; Guagnano et al., 2010).

The first evidence at odds with the action co-representation account (Sebanz et al., 2006) comes from a study of Guagnano et al. (2010) who observed that two participants performing concurrently two independent detection tasks showed a Simon effect when they acted side-by-side, but not when they were far from each other. Guagnano et al. proposed that the joint Simon effect occurs because participants spatially code their own response using the position of the co-actor as a reference point. Thus, according to the authors, the fact that another person is performing the task in close proximity, simply reintroduces the possibility to spatially code two response alternatives.

In the same vein, a recent study of Dolk et al. (2011) provided evidence against the action co-representation account. The authors combined the auditory version of the joint Simon task with the so-called rubber hand illusion (RHI; Botvinick & Cohen, 1998).

The RHI refers to the finding that when participants see a rubber hand (or another person’s hand) stroked synchronously with their own hidden hand, they feel the illusion of ownership of the rubber hand. Importantly, the same illusion does not occur when the rubber and the participant hands are stroked asynchronously. In Dolk's et al. study participants sat on the right and performed the Go/NoGo task with the right hand while their left hand was occluded from their view. The confederate sat on the left and performed the complementary Go/NoGo task with the left hand. During the task left hands of the participant and the confederate were stroked both synchronously and asynchronously in separate blocks, thus to induce or not a sense of ownership over the co-actor's hand. The rationale behind this manipulation was the following: If the joint Simon effect reflects the integration of the co-actor's action into one's own action planning then the Simon effect should be larger in the synchronous than in the asynchronous stroking condition. Yet, the results showed the opposite pattern, that is, the Simon effect was larger in the asynchronous stroking condition (i.e., when participants perceived the co-actor's hand as separated from themselves). According to Dolk et al., the larger Simon effect observed in the asynchronous stroking condition is probably due to the fact that this manipulation emphasized the existence of an alternative action, thus providing participants with a reference to spatially code their own action. On the basis of these results, Dolk et al. proposed the so-called *referential coding account* of the joint Simon effect. Following this account, the joint Simon effect it not really a social phenomenon but it occurs because the presence of another individual, sitting next to the participant and performing the complementary task, constitutes a salient event that provides participants with an alternative action, thus allowing them to spatially code their own response. Importantly, in a follow up study they demonstrated that any salient event, not necessary a response emitted by another person (e.g., even the movement of a ticking metronome), can represent an action alternative to that of the participant (i.e., an action from which the participant's response has to be discriminated), which may induce the spatial coding of the participant's response[6] (Dolk et al., 2013, see also Dittrich et al., 2012)[7].

It is important to note that the action co-representation and the referential coding accounts share the assumption that in joint tasks the involvement of another person leads participants to represent an alternative action. Consistently, Sebanz et al. (2003, Experiment 2) observed that no Simon effect occurs when the co-actor merely sat next to the participant, without emitting any responses: In this case, indeed, there cannot be any alternative action. The two accounts, however, differ from each other with respect to the nature of the joint Simon effect: social (for the action co-representation account) versus spatial (for the referential coding account). Indeed, following to the action co-

[6] Note that the referential coding account can also explain the occurrence of the joint SNARC effect (Atmaca et al., 2008), given that the SNARC effect, just like the Simon effect, is caused by a match or a mismatch between stimulus and response spatial dimensions. However, this alternative interpretation cannot account for the joint flanker effect (Atmaca et al., 2011), given that the flanker effect does not depend on the spatial coding of the response position. Yet, it is worth noting that while the Simon effect arises only from one type of conflict, that is, that between the irrelevant stimulus dimension (stimulus position) and the relevant response dimension, the flanker effect can result from two types of conflicts: that between the relevant dimensions of the targets and the distractors and that between the responses that are mapped onto targets and distracters (see Kornblum et al., 1999, and Hommel, 2011). Thus, the conflict between the relevant dimensions of the targets and the distractors may sufficient to induce the flanker effect. Consistently, Atmaca et al. (2011) observed a flanker effect even in the individual Go/NoGo flanker task. As a consequence, it is reasonable to assume that in the joint flanker task the presence of another person (i.e., of an alternative action) made the response dimension relevant, thus causing a larger flanker effect because dependent on two types of conflicts.

[7] The importance of spatial and contextual factors can be also inferred from the finding that the transfer of stimulus-response associations, established in one joint task, to a subsequent joint Simon task (i.e., the so-called social transfer of learning) does not occur when spatial factors change across the two tasks, while it is not influenced by the manipulation of social factors (Milanese et al., 2011)

representation account, the representation of the alternative action occurs because the participant represents the co-actor's task, which happens to be his/her complementary task (see Sebanz etal., 2005). This implies that the mere knowledge about the co-actor's task should be (necessary and) sufficient to produce the Simon effect. In contrast, the referential coding account states that an alternative action is represented simply by virtue of the fact that the co-actor's response constitutes a salient event (Dolk et al., 2011). As a consequence, the participant's beliefs about what the co-actor is doing should not be (either necessary or) sufficient for the Simon effect to occur.

Typical joint Simon tasks are not suitable to disentangle between these two hypotheses and, specifically, given that the co-actor acts nearby the participants, do not allow drawing firm conclusions about whether the mere knowledge about the co-actor's task is sufficient to represent an alternative response, thus producing the Simon effect. A possible way to shed light on this question is to make the actor and the co-actor executing their own part of the task in different rooms. If simply knowing that another person is responding to the complementary color is sufficient to spatially code the alternative action associated to this color, the joint Simon effect should occur even when the co-actor performs his/her part of the task in a different room. Conversely, if what allows participants to represent the alternative action is the fact that the co-actor represents a salient event then no Simon effect should be observed when the co-actor executes his/her task in a different room.

This possibility is addressed in three experiments of Study 2. Two recent studies (Tsai et al., 2008; Ruys & Aarts, 2010) seem to demonstrate that the mere belief of co-acting with another person is sufficient to induce the joint Simon effect. In these studies, indeed, the Simon effect was observed despite the actor and the co-actor performed the task in two different rooms. However, some methodological aspects of these studies do not allow drawing firm conclusions about this question.

3

Study 1

Task sharing can change the fate of task irrelevant information

3.1 INTRODUCTION

As discussed in Chapters 1 and 2, different studies by employing the joint version of well-known interference paradigms demonstrated that when participants in a pair are engaged in the same task, taking turns in responding to different values of the same target stimulus, they show interference effects that do not usually occur when they perform the same part of the task individually (Atmaca et al., 2011, 2008; Sebanz et al., 2003). These findings provided converging evidence supporting the assumption that, in joint tasks, participants co-represent the partner's task to such an extent that performance is affected as if they were performing the partner's task as well (Knoblich et al., 2011; Knoblich & Sebanz, 2006; Sebanz et al., 2006).

In a recent study, however, Heed et al. (2010) reported a finding that questions the possibility that the occurrence of interference effects in joint tasks is an outcome generalizable to all conditions in which two individuals work together on the same task. Indeed, Heed et al. observed that participants engaged in a visual-tactile interference task requiring them to respond to tactile stimuli while ignoring visual distractors, showed a reduction of the interference effect produced by visual stimuli when another person was concurrently in charge of them. The results of this study demonstrate that task sharing can also lead to a facilitation effect (i.e., a reduction of interference produced by distractor stimuli) instead of necessarily producing (or increasing) interference.

As mentioned in Chapter 2, the contrasting results observed by Heed et al. might be due to the fact that stimuli from two different sensory modalities were distributed between the actor and the co-actor (cf. Knoblich et al., 2011). However, this discrepancy might also be accounted for by the fact that in the paradigm adopted by Heed et al. the actor and the co-actor were responsible for two different stimuli, as compared with joint Simon-like tasks wherein the two co-acting participants were in charge of two different values of the same target stimulus.

Study 1 aimed at testing this latter hypothesis by exploiting the joint version of the PWI task (Rosinski et al., 1975), which involves the simultaneous presentation of two different stimuli from the same, visual modality.

The PWI paradigm is considered a variant of classical Stroop task (McLeod, 1991) and it is a widely used task in studying the mechanisms underlying language production.

In the PWI paradigm, participants are presented with a picture and a word superimposed on it and they are required to name the target picture while ignoring the distractor word. Despite the instructions to ignore the word, participants cannot help reading and processing the word, as attested by the finding that the relationship between the target and the distractor words influences the time needed to name the picture (e.g., Cubelli, Lotto, Paolieri, Girelli, & Job, 2005; Lupker, 1982). For instance, naming RTs are usually slower when the picture (e.g., a carrot) is shown with a word belonging to the same semantic category (e.g., pumpkin) than when it is accompanied by a semantically-unrelated word (e.g., lion). This effect is known as semantic interference effect (Rosinski et al., 1975) and it is thought to be due to a selection-by-competition process that occurs at the level of lexical node selection (Levelt, Roelofs, & Meyer, 1999; but see Mahon, Costa, Peterson, Vargas, & Caramazza, 2007 for a different account). In a nutshell, the core assumption of competitive theories is that the selection of a target noun depends on the activation levels of both target and non-target names. The lexical nodes with the highest activation is selected and further processed. A direct consequence of this assumption is that the higher the activation level of non-target nodes is, the more time is needed to select the appropriate target node. Thus, when the target and distractor words belong to the same semantic category, the distractor node is highly activated, receiving this node activation from two different sources: the target picture and the distractor word. Conversely, when the target and the distractor words belong to different semantic categories, the distractor node receives activation only from the distractor word, which makes the semantically-unrelated distractor a weaker competitor than the semantically-related distractor.

The occurrence of the semantic interference effect in PWI paradigms is interpreted as the demonstration that word reading occurs automatically (see Posner & Snyder, 1975 for a definition of automaticity). This assumption is further supported by the observation that when task instructions require participants to read the word instead of naming the picture, the semantic interference effect does not show up (Glaser & Düngelhoff, 1984).

Given that the PWI involves the simultaneous presentation of two different stimuli (i.e., a target picture and a distractor word), it can be split in two independent parts, that is, to name the picture and to read the word, which can be assigned to two co-acting individuals working simultaneously on two different stimuli involving the same sensory modality. For this reason, the PWI appears particularly appropriate to verify the hypothesis that the disappearance of the interference effect observed by Heed et al. (2010) was not due to the fact that stimuli from different sensory modalities were distributed between the actor and the co-actor, but rather to the fact the co-actor is working simultaneously on the task irrelevant information. If this hypothesis were correct, then sharing a PWI paradigm with a co-actor responsible for the distractor words (i.e., the task irrelevant information) should allow participants to ignore these stimuli, thus reducing the semantic interference effect

3.2 EXPERIMENT 1

In Experiment 1, participants were required to perform the typical PWI task first individually (i.e., baseline task) and then co-acting with another person (i.e., joint task). The joint task was identical to the baseline task except for the fact that participants were informed that they would have performed the task with another person, who was in another room, and whose task was to read the words while ignoring the pictures. Actually, participants performed the task on their own.

To control for possible practice effects, I included in the experimental design a second group of participants who, after the baseline, simply continued to execute the same task (i.e., they continued to perform the PWI task individually).

A reduction of the semantic interference effect in the joint condition would provide evidence supporting my hypothesis that sharing an interference paradigm with another person, concurrently responsible for the task-irrelevant stimuli, can allow participants to succeed in ignoring these stimuli just because another person is taking care of them, regardless of the fact that the two stimuli, assigned respectively to the actor and to the co-actor, share or not the same sensory modality.

3.2.1 Method

3.2.1.1 Participants

Thirty-two students (3 males, aged 19-28 years) of the University of Trento participated in the experiment. All participants were native speakers of Italian, they had normal or corrected-to-normal vision and they were naïve to the purpose of the experiment.

3.2.1.2 Apparatus and Stimuli

Participants seated about 60 cm from the screen. The experiment was run using the E-Prime 1.1.4.1 software system (Psychology Software Tools, Inc., Pittsburgh, PA). Naming responses were collected with a voice key.

Stimuli (targets and distractor words) were the same used by Cubelli et al. (2005 - Experiment 1). Target stimuli were 16 pictures – belonging to different semantic categories – selected from the set of Snodgrass and Vanderwart (1980) and presented as black line drawings on a white background. Each target picture was paired with two distractor nouns of the same semantic category (semantically-related trials) and two distractor nouns of a different semantic category (semantically-unrelated trials). Overall 64 distractor words were chosen. The target and the distractor nouns were matched for a number of variables and they did not differ for length, frequency, familiarity, typicality, age of acquisition, and phonological overlap between the pairs of target and distractors (see Cubelli et al., 2005 for further details). A set of 16 additional pictures and 32 additional distractor words were also selected and used as filler stimuli. Target and distractor nouns belonging to the filler set were all semantically and phonologically unrelated. Both target pictures and distractor words were presented in the center of the screen. The size of each picture was 6 × 6 cm, whereas distractor words appeared in upper case format (e.g., MOUSE), Courier new 18-point bold font.

3.2.1.3 Procedure

Once recruited for the experiment, participants were randomly assigned to one of two experimental conditions: social or control condition (see Figure 3.1). In each condition, participants performed the PWI task twice, first individually (baseline task) and then either co-acting with another person (social condition) or again individually (control condition). Despite of the implementation of a within subjects design, the baseline and the joint tasks were not counterbalanced across participants. The reason is that if the joint task comes first, the impact of this task could persist in the individual task, thus

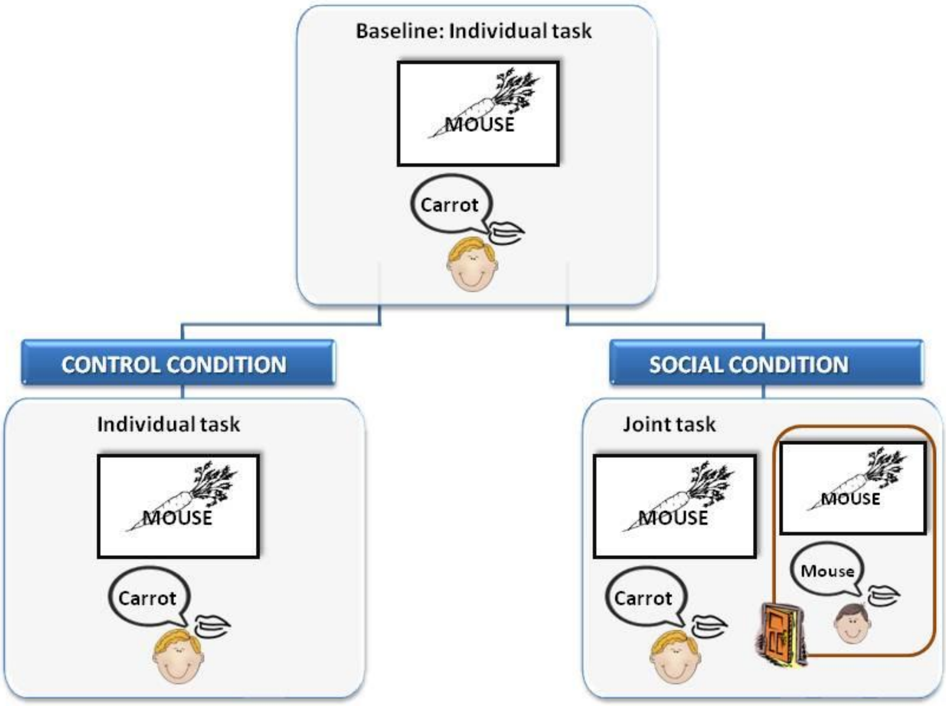

Figure 3.1. Schematic representation of the experimental design adopted in Experiment 1. Participants were randomly assigned to one of two experimental conditions: control or social. Each experimental condition comprised two tasks (i.e., the baseline individual task and the critical task). Conditions were defined as either control or social depending on the task participants performed after the baseline task. Participants assigned to the control condition, after completed the baseline, simply continued to perform the same task individually. In contrast, participants assigned to the social condition, after the baseline, were required to perform the same task with an alleged co-actor who was in a not-specified room and was thought to read the distractor words.

preventing the possibility to have a true individual task as a baseline for comparison (cf. Huguet et al., 1999).

In all tasks, trials began with the presentation of a fixation cross displayed in the center of the screen. After 500 ms the fixation cross was replaced by a picture-word pair, which remain on the screen until the response but no more than 2000 ms. The target picture was always presented simultaneously with the distractor word. Offset of the picture-word pair was followed by a blank of 700 ms. Participants were instructed to name the target picture by producing the corresponding bare noun as quickly and accurately as possible while ignoring the distractor word. Errors and malfunctioning of the voice key were recorded online by the experimenter. In the joint task, participants performed the task with an alleged partner, who was in a non-specified room and was thought to read the distractor words. To online remind participants that another person was engaged in the task, a visual feedback (i.e., a green O) was presented in the center of the screen at the end of the blank to signal participants whether the co-actor had responded or not. Participants were informed that this feedback was non-informative about the co-actor's speed and accuracy. Indeed, they were told that, since the co-actor's response might have overlapped in time with their response, the feedback would have been provided always at the end of each trial.

Each task consisted of 96 trials, in which each picture-word pair was presented once. Among these trials, 32 were fillers and were not considered in the analyses. The remaining 64 trials were half semantically-related and half semantically-unrelated. Pseudorandom experimental lists were created according to the following criteria: (a) the first two trials were filler; (b) either semantically-related or –unrelated pairs could appear in no more than three consecutive trials; (c) target belonging to the same semantic category could not appear in consecutive trials. In all tasks, experimental trials were preceded by 8 practice trials, in which both target pictures and distractor words were different from those used in the experimental trials. To allow participants to familiarize with the experimental pictures and to induce the use of the expected name, before the baseline, participants were presented with all pictures twice with a string of 5 #s instead of the distractor word and were asked to name them. After naming the picture, the string of #s was replaced by the corresponding picture name, which was shown on the screen for 2000 ms.

3.2.2 Results and discussion

Four type of responses were excluded from the analyses: (a) naming errors; (b) failures by the voice key to record the response; (c) verbal disfluences that triggered the voice key; (d) RTs exceeded two standard deviations from a participant's mean. Overall 10.99 % of the responses were excluded from the analysis, of which 1.66 % were naming errors. Errors were not analyzed.

For each experimental condition (control and social), correct RTs were submitted to an analysis of variance (ANOVA) with two within-subjects factors: task (baseline vs. second task) and semantic relatedness (semantically-related vs. -unrelated trials). The main effect of semantic relatedness was significant in both control and social conditions [both $Fs \geq 5.86$, both $ps < .05$; both $\eta_p^2 s \geq .28$]: Participants were slower in semantically-related than –unrelated trials (737 vs. 714 ms and 747 vs. 729 in the control and social conditions, respectively). Task was significant only in the social condition [$F(1, 15)=4.94$, $p<.05$, $\eta_p^2 = .25$]: Participants were faster in the joint than in the baseline task (727 vs. 750 ms). The Task×Semantic relatedness interaction was significant neither in the control nor in the social condition [both $Fs \leq .72$, both $ps \geq .41$, both $\eta_p^2 s \leq .004$], indicating that the semantic interference effect was present in both the baseline and the second task (i.e., the repetition of the individual PWI task in the control condition and the joint task in the social condition; see Figure 3.2).

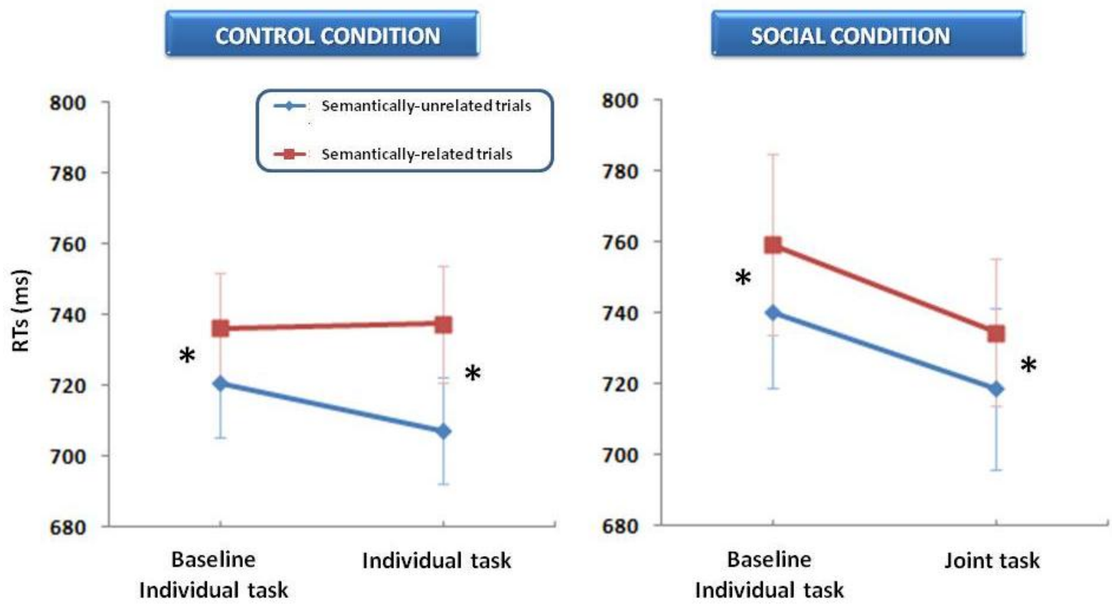

Figure 3.2. Means (± S.E.M.s) of correct RTs for each experimental condition in Experiment 1. For each condition, RTs are plotted as a function of task (baseline vs. second task) and semantic relatedness (semantically-related vs. -unrelated trials). Asterisks indicate the presence of the semantic interference effect.

These results were confirmed by mixed effect regression analyses[8] carried out taking participants and items as random effects (see Baayen, Davidson, & Bates, 2008 for further details about the statistical procedure). In each condition, models were fitted by initially defining the simplest models with participants and items as random factors. These models were then enriched by subsequently adding the two fixed factors: semantic relatedness first and then task. Finally, the interaction between task and semantic relatedness was added to the models. Once all models were defined, the best fitting model (i.e., the model that significantly improved the fit of the data) was selected by comparing, through a log-likelihood test, the goodness-of-fit of the model before and

[8] Mixed effect regression analyses were carried out using lme4 (Bates & Maechler, 2010) and Language R (Baayen, 2008) packages implemented in the open-source statistical program R (R development core team, version 2.15.0).

after enriching it with an additional factor. For the control condition, the best fitting model included, besides the two random factors (i.e., participants and items), only the fixed factor semantic relatedness, which significantly improved the fit (χ^2=15.82, p<.001). For the social condition, the best fitting model included, besides the two random factors, the fixed factors semantic relatedness and task, which significantly improved the fit (χ^2=16.11, p<.001). Models which additionally included the Task×Semantic relatedness interactions did not further improve the fit in both conditions (both $\chi_s^2 \leq 2.84$, both $p_s \geq .24$).

In the present experiment the semantic interference effect was observed in both conditions and was not modulated by the type of task participants performed after the baseline. Indeed, this effect was still observed not only in the group of participants who continued to perform the PWI task individually but also in the group of participants who performed the joint task. Thus, in contrast with our predictions, task sharing had no influence on the size of the semantic interference effect. The social manipulation seems only to reduce significantly participants' naming RTs, which is considered a typical outcome in case of simple tasks performed in presence of other individuals (i.e., social facilitation effect; Guerin, 1993; see also Section 1.1).

However, this does not necessary mean a failure to replicate the finding observed by Heed et al. (2010). The null result observed in the present experiment can be trace back to the automaticity of written word recognition that may prevent participants from ignoring the distractor words. In other words, participants cannot avoid reading and processing written words even if they know that another person is in charge of these stimuli. If this were the case, any experimental manipulation able to hamper written-word recognition should provide participants time enough to filter distractor words out from their task representation. Of course, this outcome is expected only when someone else is taking care of distractor words.

This possibility was addressed in Experiment 2.

3.3 EXPERIMENT 2

The aim of this experiment was to verify the possibility that when written-word recognition in the PWI task is delayed or impaired, the belief of co-acting with another person – responsible for the distractor words – may allow participants to ignore these stimuli (i.e., the co-actor’s stimuli). That should turn into the disappearance or (at least) the reduction of the semantic interference effect in the joint task. To this end, distractor words were shown in case alternation letters. Case alternation has been found to delay word recognition (e.g., Mayall, Humphreys, & Olson, 1997), but, importantly, it does seem to modulate interference effects that occur in PWI tasks (see Miozzo & Caramazza, 2003).

As in Experiment 1, participants performed the PWI task first individually (baseline) and then either they continued to perform the task individually (control condition) or co-acting with an alleged co-actor who was thought to read the distractor words (social condition; see Figure 3.3).

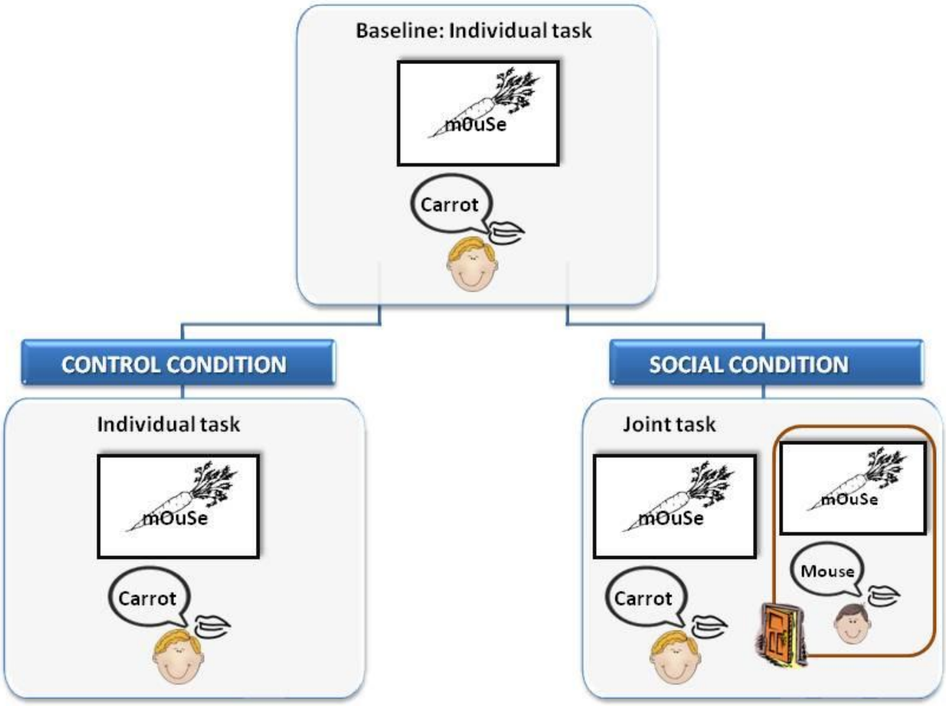

Figure 3.3. Schematic representation of the experimental design adopted in Experiment 2. The experimental design was identical to that of Experiment 1: Participants were randomly assigned either to the control or to the social condition. After completed the baseline task, they were required either to continue to perform the PWI task individually (control condition) or with a co-actor who was supposed to read the distractor words (social condition). In contrast with Experiment 1, distractor words were shown in case alternation letters.

3.3.1 Method

3.3.1.1 Participants

Thirty-two students (3 males, aged 19-28 years) of the University of Trento who were all native speakers of Italian took part to the experiment. They all had normal or corrected-to-normal vision, did not participate to the Experiment 1 and were naïve to the purpose of the experiment.

3.3.1.2 Apparatus, Stimuli and procedure

The apparatus, stimuli, procedure and the experimental design were the same as those in Experiment 1 with the following exception: Distractor words were shown with alternated case (e.g., mOuSe).

As in Experiment 1, participants were randomly assigned to one of two experimental conditions: social or control condition.

3.3.2 Results and discussion

Data were processed following to the same procedure used in Experiment 1, and 10.89 % of the data points were removed (2.40 % were naming errors). Correct RTs were submitted to the same analyses carried out in Experiment 1. Task was significant only in the social condition [$F(1, 15)=8.08$, $p<.05$, $\eta_p^2=.35$]: Participants were faster in the joint than in the baseline task (733 vs. 760 ms). The main effect of semantic relatedness was significant in both control and social conditions [both $Fs\geq10.88$, both $ps<.01$; both $\eta_p^2s\geq.42$] with participants slower in the semantically-related than –unrelated trials (747 vs. 725 ms and 756 vs. 737 ms in the control and social conditions, respectively). The Task×Semantic relatedness interaction was not significant in the control condition [$F(1, 15)=.30$, $p=.60$; see Figure 3.4]. Semantic interference effects of 25 and 20 ms were observed in the baseline and in the repetition of the PWI task, respectively. Most importantly, this interaction was significant in the social condition [$F(1, 15)=5.33$, $p<.05$, $\eta_p^2=.26$]. Post-hoc analysis (Newman-Keuls) revealed that the difference between semantically-related and –unrelated trials (775 vs. 744 ms and 736 vs. 731 ms in the baseline and joint tasks, respectively) was significant in the baseline task ($p<.005$) but not in the joint task ($p=.53$). These results were confirmed by mixed models analyses. For the control condition, the best fitting model included, besides the two random factors, only the fixed factor semantic relatedness, which significantly improved the fit ($\chi^2=15.63$, $p<.001$). For the social condition, the best fitting model was the most complex one (i.e., the model including, besides the two random factors, both the two fixed factors and their interaction), which significantly improved the fit ($\chi^2=4.61$, $p<.05$).

In this experiment I observed the semantic interference effect although alternated-case distractor words were used. As previously stated, this manipulation is thought to impair

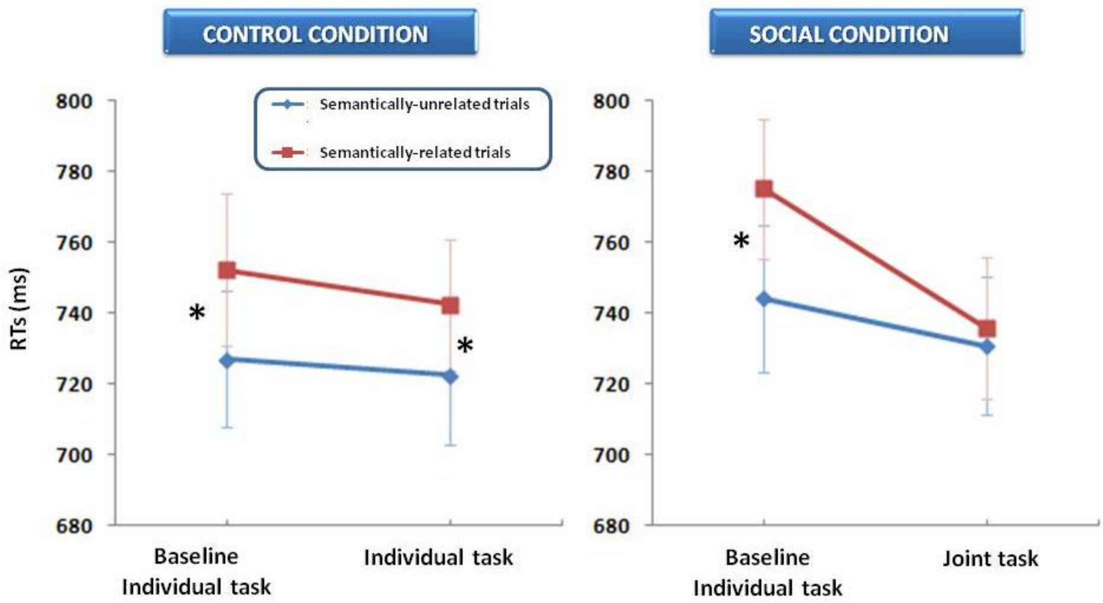

Figure 3.4. Means (± S.E.M.s) of correct RTs for each experimental condition in Experiment 2. For each condition, RTs are plotted as a function of task (baseline vs. second task) and semantic relatedness (semantically-related vs. -unrelated trials). Asterisks indicate the presence of the semantic interference effect.

written-word recognition (e.g., Mayall et al., 1997) but nevertheless it does not seem to influence the size of interference effects that occur in PWI tasks. This finding is consistent with that of Miozzo and Caramazza (2003).

More interestingly, the results of the present experiment demonstrate that when written-word recognition is impaired – here, by case alternation – the mere belief of co-acting with another individual, besides speeds up participants' RTs (as already observed in the social condition of Experiment 1), eliminates the semantic interference effect. This latter finding cannot be attributed to the significant reduction of RTs. Indeed, the semantic interference effect continued to be present in the social condition of Experiment 1 despite participants were significantly faster in the joint than in the baseline task.

The results of the social condition of Experiment 2 can instead be explained by assuming that task sharing led participants to succeed in ignoring the distractor words because another person was in charge of them. Furthermore, given that in the PWI paradigm the target and the distractor stimuli share the same sensory modality, the present results allow rejecting the hypothesis that the disappearance of the interference effect observed by Heed et al. (2010) is strictly restricted to the tasks in which stimuli from different sensory modalities are distributed between two participants. Conversely, the disappearance of the interference effect seems to be due to the fact that the co-actor is thought to work simultaneously on the task irrelevant information. The information about the co-actor's task in a context of impaired word recognition would provide participants with an effective strategy to ignore the distractor stimuli that are in charge of someone else.

Thus, the facilitation effect seems to emerge only when the actor and the co-actor work on different stimuli.

However, an alternative interpretation deserves to be considered. The disappearance of the semantic interference effect may have been caused by a mere social facilitation effect: Knowing that another person was involved in the task might have had a distracting effect and, in order to fully concentrate on the task, participants might have narrowed their attention on the relevant information (the pictures) and suppressed the processing of all stimuli unrelated to their task (the distractor words; cf. Baron, 1986; Huguet et al., 1999; see also Section 1.1.1). If this were the case, then what the co-actor is supposed to do is irrelevant and the semantic interference effect should disappear also when the co-actor is thought to be in charge of the same stimuli as the participant. In contrast, if what allowed the semantic interference effect to disappear was the fact that the co-actor was thought to work on different stimuli, then the semantic interference effect should persist when the co-actor is thought to be in charge of the same stimuli as the participant.

To rule out this alternative interpretation I run Experiment 3.

3.4 EXPERIMENT 3

Experiment 3 aimed at excluding the possibility that the disappearance of the semantic interference effect observed in the social condition of Experiment 2 was simply due to a social facilitation effect. To this end, once completed the individual (baseline) task, participants were required to perform a joint task in which the co-actor was thought to work either on the distractor words (joint–different target task) or on the pictures (joint–same target task). In contrast with Experiments 1 and 2, target pictures were randomly shown in nine different colors, whereas distractor words were shown in case alternation letters (and in black), as in the Experiment 2.

In the joint task in which the participant and the co-actor were supposed to work on different target stimuli, participants were informed that the co-actor was reading the distractor words and ignoring the pictures. The instructions of this joint task were identical to those of Experiments 1 and 2 and, thus, they emphasized the fact the co-actor was taking care just of those stimuli that the participant had to ignore. Conversely, in the joint task in which the participant and the co-actor were supposed to work on the same target stimuli, participants were told that the co-actor was naming the color of the pictures and ignoring the words. In this case, the instructions emphasized the fact that the co-actor was taking care of a different aspect of the same target stimuli assigned to the participant and that nobody was taking care of the distractor words.

Importantly, in both joint tasks, the co-actor was supposed to perform a different task, thus preventing the occurrence of possible competitive (or social comparison) effects (cf. Huguet et al., 1999).

As in the previous experiments, to rule out possible practice effects, I included a control condition in which participants continued to perform the PWI task individually.

The following predictions can be made. First of all, the semantic interference effect should occur in the baseline task of all experimental conditions and it should continue to be present in the repetition of the task. There is no reason, indeed, to expect that the semantic interference effect can be modulated by the presentation of colored target pictures. Even though the use of colors might make the pictures more salient and might help participants to direct the attention on these stimuli, it should not be sufficient to prevent them from reading the distractor words, thus to reduce the semantic interference effect.

Secondly, I expect the semantic interference effect to disappear in the joint task in which the co-actor is thought to be in charge of the distractor words, thus replicating the finding observed in the joint task of Experiment 2.

Most importantly, if the disappearance of the semantic interference effect observed in the joint task of Experiment 2 was due to a generic social facilitation effect, then the semantic interference effect should disappear even in the joint task in which the co-actor is thought to name the color of the pictures. Following the social facilitation theories, indeed, the distracting effect produced by the involvement of another person in the task should give rise to a narrowing of the attention on the target stimuli, regardless of the co-actor's task. Conversely, if what caused the semantic interference effect to disappear was the fact that the co-actor was simultaneously taking care of the distractor words (i.e., s/he was working on different stimuli), then the semantic interference effect should continue to be present in the joint task in which the co-actor is supposed to name the color of the pictures. In this case, indeed, given that nobody is taking care of the distractor stimuli, participants are not supposed to ignore these stimuli.

3.4.1 Method

3.4.1.1 Participants

Sixty-four students (5 males, aged 19-28 years) of the University of Trento who were all native speakers of Italian took part to the experiment. They all had normal or corrected-to-normal vision, did not participate to the Experiments 1 and 2, and were naïve to the purpose of the experiment.

3.4.1.2 Apparatus, Stimuli and procedure

The apparatus, stimuli, procedure and the experimental design were the same as those in Experiment 2 with the following exception: Target pictures were presented as colored line drawings. Nine different colors were used: red, pink, azure-blue, yellow, brown, orange, blue, green and violet. The color of the target pictures varied randomly with the restrictions that a) pictures of the same color could not appear in consecutive trials, and b) the color of picture was in no way related to the depicted object (e.g., the carrot was never shown in orange).

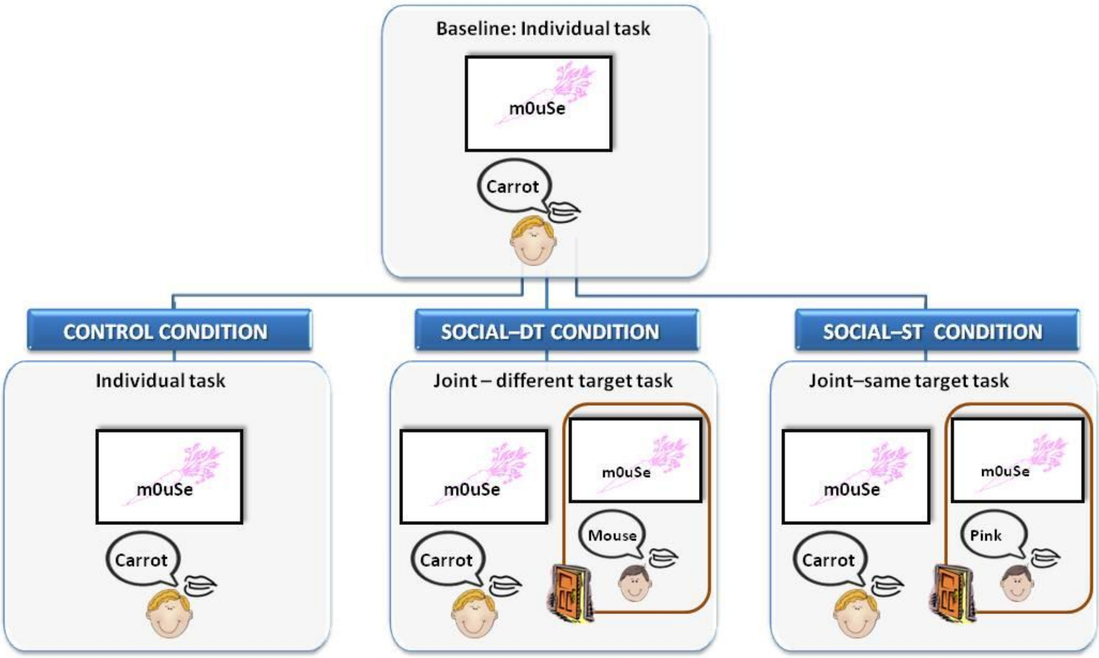

Figure 3.5. Schematic representation of the experimental design adopted in Experiment 3. Participants were randomly assigned to one of three experimental conditions: control, social–DT or social–ST. In contrast to the previous experiments, target pictures were randomly shown in nine different colors. Distractor words were shown in alternated-case letters as in Experiment 2. The control and the social–DT conditions coincided with the control and social conditions of the previous experiments, whereas the social–ST condition was new of this experiment. Participants assigned to this latter condition, after the baseline, performed a joint task in which they were told that the co-actor was naming the color of the pictures.

Participants were randomly assigned to one of three experimental conditions: social–different target (–DT), social–same target (–ST), or control condition (see Figure 3.5).

3.4.2 Results and discussion

Data were processed following to the same procedure used in Experiments 1 and 2, and 9.2 % of the data points were removed (1.03 % were naming errors). Correct RTs of each experimental condition were submitted to the same analyses carried out in Experiments 1 and 2.

Task was significant in both social conditions [both Fs≥5.41, both ps≤.05, both η_p^2s≥.27]: Participants were faster in the joint tasks as compared to the baseline tasks (701 vs. 729 ms in the social–ST condition and 691 vs. 712 ms in the social–DT condition). The main effect of semantic relatedness was significant in all conditions [all Fs≥12.20, all ps<.005; all η_p^2s≥.45] with participants slower in the semantically-related than –unrelated trials (704 vs. 684 ms, 728 vs. 702 ms, and 712 vs. 691 ms in the control, social–ST, and social–DT conditions, respectively). The Task×Semantic relatedness interaction was significant only in the social–DT condition [$F(1, 15)=9.14$, $p<.01$, $\eta_p^2=.38$; see Figure 3.6]. Post-hoc analysis revealed that the difference between semantically-related and –unrelated trials (729 vs. 698 ms and 695 vs. 685 ms in the baseline and joint–different target tasks, respectively) was significant in the baseline task (p<.001) but not in the joint task (p=.08). The interaction was significant neither in the control nor in social–ST conditions [both F≤.40, both p≥.40]. In the control condition, semantic interference effects of 24 and 17 ms were observed in the baseline and in the repetition of the PWI task, respectively. In the social–ST condition, semantic interference effects of 30 and 23 ms were observed in the baseline and in the joint–different target task, respectively.

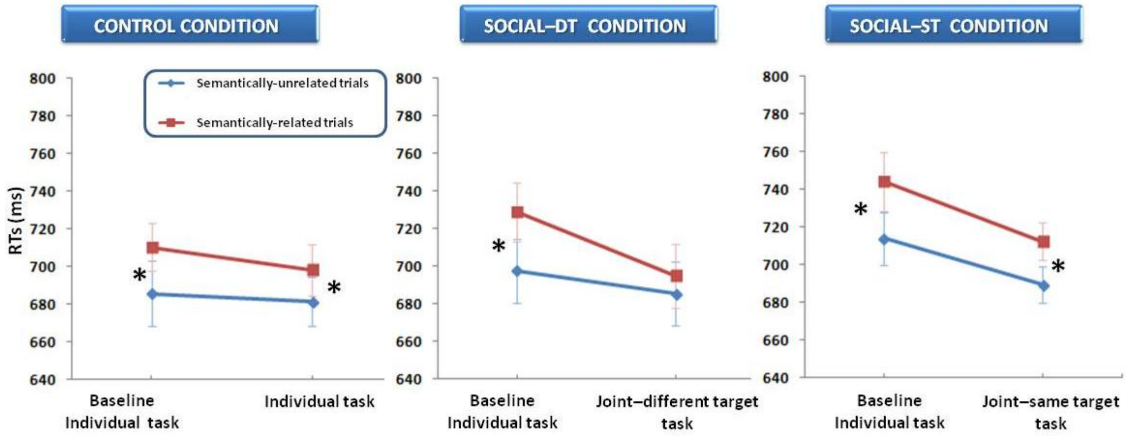

Figure 3.6. Means (± S.E.M.s) of correct RTs for each experimental condition in Experiment 3. For each condition, RTs are plotted as a function of task (baseline vs. second task) and semantic relatedness (semantically-related vs. -unrelated trials). Asterisks indicate the presence of the semantic interference effect.

These results were confirmed by mixed models analyses. For the control condition, the best fitting model included, besides the two random factors, only the fixed factor semantic relatedness, which significantly improved the fit (χ^2=18.64, p<.001).

For the social–ST condition, the best fitting model included, besides the two random factors, the fixed factors task and semantic relatedness, which significantly improved the fit (χ^2=36.62, p<.001).

For the social–DT condition, the best fitting model was the most complex one (i.e., the model including, besides the two random factors, both the two fixed factors and their interaction), which significantly improved the fit (χ^2=4.84, p<.05).

The results of Experiment 3 confirm the findings of Experiment 2: When written-words recognition is delayed by case alternation, the belief of co-acting with another individual, who is supposed to work on the distractor words, determines the disappearance of the semantic interference effect. Importantly, the results of the present experiment allow rejecting the hypothesis that the suppression of the semantic interference effect may be due to a generic social facilitation effect. Indeed, the disappearance of the semantic interference effect was observed in the joint task in which participants believed that the co-actor was reading the distractor words (joint–different target task) but not in the joint task in which the co-actor was thought to name the color of the pictures (joint–same target task). Based on social facilitation theories, I should have observed the same pattern of results in both joint tasks. According to these theories, knowing that another person in involved in the task might lead participants to focus their attention on the task relevant information and to filter out the task irrelevant information, regardless of the specific task performed by the other person.

Furthermore, the disappearance of the semantic interference effect cannot be attributed to the significant reduction of RTs either. Indeed, although the belief of co-acting with another person speeded up participants' RTs in both joint tasks, the semantic interference effect disappeared only in the joint task in which the co-actor was supposed to read the distractor words. As previously stated, the significant reduction in RTs is typically observed when people perform simple tasks in joint contexts (Guerin, 1993).

Conversely, the present findings provide a firm demonstration that what allowed participants to succeed in ignoring the distractor words was just the fact that someone else was in charge of these stimuli. Indeed, when nobody was thought to take care of these stimuli, as occurred in the individual and in the joint–same target tasks, the semantic interference effect continued to be present.

3.5 GENERAL DISCUSSION

In the present study I observed that when participants believe to perform the picture-word task with a co-actor who simultaneously is responding to the distractor words, this information makes the semantic interference effect to disappear. Very likely this result is strictly dependent on the social setting which, however, is effective only when written word recognition is made more difficult by case alternation, probably because of the automaticity of the effect investigated in this study.

Thus, the results of the Experiment 2 confirm and extend the findings reported by Heed et al. (2010). Importantly, given that in the social condition of my study participants worked on two different stimuli involving the same modality, I can rule out that this outcome is restricted to the conditions in which the co-actor performs a task which involves stimuli from a different sensory modality as that of the participant. Instead, I suggest that the reduction (or the suppression) of the interference effect can be considered as a consistent outcome resulting from sharing an interference paradigm with another person working simultaneously on the task irrelevant information.

The results of Experiment 3, besides confirming those of Experiment 2, allow ruling out that the disappearance of the semantic interference effect may have been caused by a generic social facilitation effect. As previously discussed in this chapter, this same outcome would have been expected on the basis of the attentional theories proposed within the social facilitation area (Huguet et al., 1999; Baron, 1986; Baron et al., 1978; see also Section 1.1.1). According to these theories, knowing that another person is involved in the task may threat participants with a cognitive overload (or an increased arousal), resulting from an attentional conflict between the co-actor and the task[9]. This, in turn, would cause a restriction of the focus of the attention on the task relevant information, thus increasing the ability to ignore the task irrelevant information, at least when the task involves the presentation of few stimuli. The fact that the semantic interference effect was still observed in the joint task in which the co-actor was in charge of the same stimuli as the participant (i.e., in the joint–same target task of Experiment 3) rules out such a kind of explanation.

Furthermore, it is hardly likely that the disappearance of the semantic interference effect may be traced back to the establishment of a possible competitive relationship between the participant and the alleged co-actor. Indeed, competitive mechanisms do not usually build up when the actor and the co-actor perform different tasks, as in this case it does not make any sense to compare one's one performance with that of the other person (cf. Sanders et al., 1978). In addition, if this were the case, a competitive mechanism should have been developed also in the joint task in which the co-actor was naming the color of the pictures, thus determining the disappearance of the interference effect in this task as well.

In contrast, the disappearance of the semantic interference effect seems to be critically related to the fact that the co-actor was thought to take care just of those stimuli that the participant had to ignore because they were irrelevant to perform the task.

Consistently with Heed et al. (2010) interpretation, I propose that the belief of co-acting with another person who simultaneously takes care of the task irrelevant stimuli allows

[9] Importantly, it has been shown that for social facilitation effects to occur, the physical presence of the co-actor is not necessary (see Dumas et al., 2005).

participants to filter out these stimuli from their task representation, just because another person is in charge of them. In other words, task sharing may induce the implementation of a division-of-labor between the two participants such to allow the task irrelevant information, which is usually destined to be processed, to be instead ignored. Probably the implementation of this division-of-labor is achieve through an intentional weighting mechanism (Hommel et al., 2001), operating on participants' task representation: Knowing that another person is in charge of the distractor stimuli makes participants to increase the weight (and thus the salience) of the task relevant information (i.e., of their own stimuli) at the expense of the task irrelevant information (i.e., the co-actor's stimuli), which then is easily discarded from the representation of the own task. That said I can assume that distractor words are filtered out at the perceptual level.

This proposal is in line with other findings showing the role of top-down factors such as intention, attention and task set in modulating automatic processes (see Kiefer, 2007).

To conclude, even though these findings do not question the assumption underlying the action co-representation account that task sharing induces participants to represent also the co-actor's task (Sebanz et al., 2006), they cast some doubts on the fact that this necessarily leads participants to integrate this latter task and the co-actor's action into their own task representation. Indeed, the present data suggest that representing the co-actor task can also induce to exclude it from one's own task representation. Thus, it can be advanced the hypothesis that joint tasks can determine both integration and division processes. However, the former leads to response conflict and, thus, to interference effects, whereas the latter causes the reduction of interference effects. As I have previously suggested, the kind of paradigm that participants are required to share can be responsible for the occurrence of either integration or division processes. For instance, it is possible that integration processes occur when the actor and the co-actor take turns in responding to different values of the same target stimulus, as happens in joint Simon-like tasks, whereas division processes become necessary and fruitful when the two interacting participants are responsible for different stimuli.

However, it is also possible that the occurrence of interference effects in joint Simon-like paradigms is caused by the combination of different factors. For example, nowadays there is a quite heated debate on the mechanisms underlying the joint Simon effect. This debate was triggered by the results of recent studies that raised some doubts on the social nature of this effect by demonstrating, for example, that any salient event occurring on the side opposite to the participant's position (e.g., the presence of a clock) is sufficient to induce it (Dolk et al., 2013; see also Dittrich et al., 2012; Dolk et al., 2011; Guagnano et al., 2010).

This question is addressed in Study 2.

4

Study 2

When task sharing eliminates the Simon effect

4.1 INTRODUCTION

Study 2 aimed at shed light on the mechanisms underlying the joint Simon effect. Two different accounts can be distinguished: the action co-representation account (Sebanz et al., 2006; Sebanz et al., 2005) and the referential coding account (Dolk et al., 2013; Dittrich et al., 2012; Dolk et al., 2011; Guagnano et al., 2010). According to the action co-representation account, the joint Simon effect reflects the fact that, in joint Go/NoGo Simon tasks, participants co-represent the co-actor's task and integrate his/her response in their own task representation as if they were executing the co-actor's response as well. Thus, on the basis of this account, the joint Simon effect would be mainly a social phenomenon and it would demonstrate that task representations are socially shared. Conversely, according to the referential coding account, the joint Simon effect occurs simply because the presence of another person, sitting next to the participant and performing a task, represent a salient event that provides participants with an alternative action for spatially coding their own response. Thus, on the basis of this account, the joint Simon effect would be mainly a spatial phenomenon.

It is interesting to note that both interpretations share the idea that in joint Simon tasks the presence of another person – actively involved in the task – allows participants to represent also the alternative action: The representation of two spatially distinct action alternatives, in turn, leads to a match or a mismatch between stimulus and response sets, which gives rise to the Simon effect (Kornblum et al., 1999). However, following the action co-representation account, the representation of the alternative action is induced by knowing that the co-actor is performing the complementary task. A logical implication is that the mere knowledge about the co-actor's task, besides being necessary, should also be sufficient to give rise to the Simon effect. Conversely, according to the referential coding account, the alternative action is represented simply because the co-actor's response constitutes a salient event occurring on the side opposite to the participant's response position. As a consequence, knowing the co-actor's task should be neither necessary nor sufficient for the Simon effect to occur.

Based on these premises, the problem of disentangling between these two accounts can be turn into the question of verifying whether the mere knowledge about the co-actor's task is sufficient to represent the alternative response, thus producing the Simon effect.

A possible way to shed light on this question is to make the actor and the co-actor executing their own part of the task in different rooms. If knowing that another person is responding to the complementary color is sufficient to spatially code the alternative action associated to this color, the joint Simon effect should occur even when the co-actor performs his/her part of the task in a different not-specified room. Conversely, if what allows participants to represent the alternative action is the fact that the co-actor represents a salient spatially-connoted event, no Simon effect should be observed when the co-actor executes his/her task in a different not-specified room.

Two recent studies (Tsai et al., 2008; Ruys & Aarts, 2010) seem to demonstrate that the mere belief of co-acting with another person is sufficient to induce the joint Simon effect. In these studies, indeed, the joint Simon effect was observed despite the actor and the co-actor performed the task in two different rooms (but see Welsh et al., 2007 for contrasting results). However, some methodological concerns do not allow drawing firm conclusions about this question.

In Tsai's et al. (2008) study, participants sat alone in a room and were instructed to press the right button of a computer mouse when a lateralized green square appeared on the screen and to refrain from responding when a red square was presented. They were told that they would have performed the task with another individual, who was in another room and would have responded to the complementary color (the red square) by pressing the left button. A Simon effect was observed: Responses were faster when the target position corresponded to the participant's response button (i.e., the target was on the right) than when it did not correspond (i.e., the target was on the left). In line with the action co-representation account, the Simon effect observed by Tsai et al. could be explained by assuming that the belief of co-acting with another individual responsible for the complementary color let participants to activate, not only the representation of the action they had to execute, but also the representation of the co-actor's action. Yet, this effect could be traced back to spatial factors rather than to the knowledge about the co-actor's task. That is, the representation of both left and right responses might have been prompted by the use of the mouse as response devise. It is well-known that, although the Simon effect does not usually occur in individual Go/NoGo tasks in which only one response is mentioned (Callan et al. 1974), there are several exceptions to this rule: The Simon effect may occur when the experimental conditions lead participants, not only to activate the required response, but also to code another (non-active) response; for example, when the Go/NoGo task is preceded by a two-choice task in which participants used two response buttons (Ansorge & Wühr, 2009, 2004). The representation of a response, activated in the two-choice task, is transferred to the subsequent task, even though in the second task this response is no longer task relevant. Similarly, the practice in daily life with the left mouse button, which is more frequently used than the right one, could lead participants to activate, during the Go/NoGo task, the representation of the left button in addition to that of the right one (the required response button), thus inducing the Simon effect.

Since in Tsai's et al. (2008) study all participants responded to the Go stimuli by pressing the right mouse button, and given that participants never performed the Go/NoGo task individually, the occurrence of the Simon effect in their joint task cannot be unequivocally ascribed to the belief of co-acting with another person.

A similar line of reasoning can account for the joint Simon effect observed by Ruys and Aarts (2010). In this study, participants performed an auditory version of the joint Simon task: They were instructed to respond to either high or low tones by pressing the right key ("3" on the numerical keyboard) and to withhold the response to the other tones because another person, who was in the adjacent room, would have responded to them by pressing the left button ("z"). A joint Simon effects was observed although the co-actor was acting in a different room: Participants were faster when the sound was presented at the right ear than when it was presented at the left ear. However, the occurrence of the Simon effect can be justified by a minor detail of the experimental procedure: To online remind participants that another person was engaged in the task, the co-actor's responses were signaled with a red light occurring on the left side of the screen, whereas participants' responses were signaled with a red light occurring on the right side. The fact that the responses of both the participant and the co-actor were followed by the presentation of lateralized lights, spatially corresponding to their respective response buttons, might have allowed participants to code their own response as "right" as opposed to the left lights signaling the co-actor's response.

Thus, it remains open the question of whether the mere knowledge about the co-actor's task is sufficient to give rise to the Simon effect. The present study addressed this issue. To this end, I decided to employ a paradigm similar to that used by Tsai and colleagues (2008): Participants sat alone in a room and were required to respond to the target stimuli by pressing one of the two buttons of a computer mouse. Although only one response was requested, the response device involved a possible alternative response (i.e. the press of the non-requested mouse button). This allowed me to manipulate the task instructions to compare two critical experimental conditions. In one of them, participants were explicitly required to code spatially the alternative response: They have to imagine responding to the alternative stimulus with the alternative response. In the other condition, participants were simply told that another person was responding to the alternative stimulus.

In contrast to Tsai et al. (2008), I counterbalanced the response button position. That allowed me to test the hypothesis that different effects may be observed depending on the mouse button participants have to press, which also provided further cues for the comprehension of the impact of previous experience on spatial effects observed in standard (individual) Simon tasks (Ansorge & Wühr, 2009, 2004).

4.2 EXPERIMENT 4

Experiment 1 aimed at disentangling between the two main hypotheses advanced to explain the joint Simon effect. To this end, participants were required to perform an individual Go/NoGo task first (i.e., baseline task), which requires them to press one of the two buttons of the mouse in response to stimuli of one color only. Afterwards, they executed a second task which was identical to the baseline task except for the instructions: an imaginative two-choice task or a joint task. In the imaginative two-choice task, besides responding to the Go color, participants were also asked to imagine themselves responding to the NoGo color by pressing the alternative mouse button. In the joint task, participants continued to respond to the Go color but they also believed to perform the task with a co-actor, who was in a non-specified room and was responding to complementary (NoGo) color. Actually, participants performed the task on their own. Finally, to rule out possible practice effects a third group of participants was required to continue to perform the Go/NoGo task individually.

Given that transfer effects from one task to another are very common in this kind of tasks (Ansorge & Wühr, 2004, 2009) I preferred not to counterbalance the order of the two tasks. Therefore, all participants started with the individual Go/NoGo task, enabling me to properly consider this individual task as a baseline.

The following predictions can be made. First of all, on the basis of the difference I have previously postulated between the two mouse buttons, I expect to observe a Simon effect in the baseline task, but only for participants who respond to the Go stimuli by pressing the right mouse button. No Simon effect should emerge for those participants using the left mouse button.

In the imaginative two-choice task, which explicitly requires participants to activate the representation of the NoGo response, a Simon effect is expected, regardless of the response mouse button used to respond. In the joint task, different results are expected on the basis of the two main hypotheses advanced to explain the joint Simon effect. If the belief of co-acting with another person is sufficient to induce participants to spatially code the alternative response, as postulated by the action co-representation account, both right- and left-button participants should show a Simon effect in the joint task. Thus, participants engaged in the joint task should show the same pattern of results of those participants involved in the imaginative two-choice task. Conversely, inasmuch as the joint Simon effect depends on the fact that the co-actor's response constitutes a salient action event, given that in our paradigm the co-actor is not-physically present, no Simon effect is expected.

4.2.1 Method

4.2.1.1 Participants and experimental design

Sixty-four undergraduate students of the University of Trento (9 males; aged 19 – 31 years; all right-handed) participated in the experiment. All participants were naïve about the purpose of the experiment and they had a normal or correct-to-normal vision.

Once recruited for the experiment they were randomly assigned to one of three experimental conditions (control, imaginative or social). Sixteen participants were

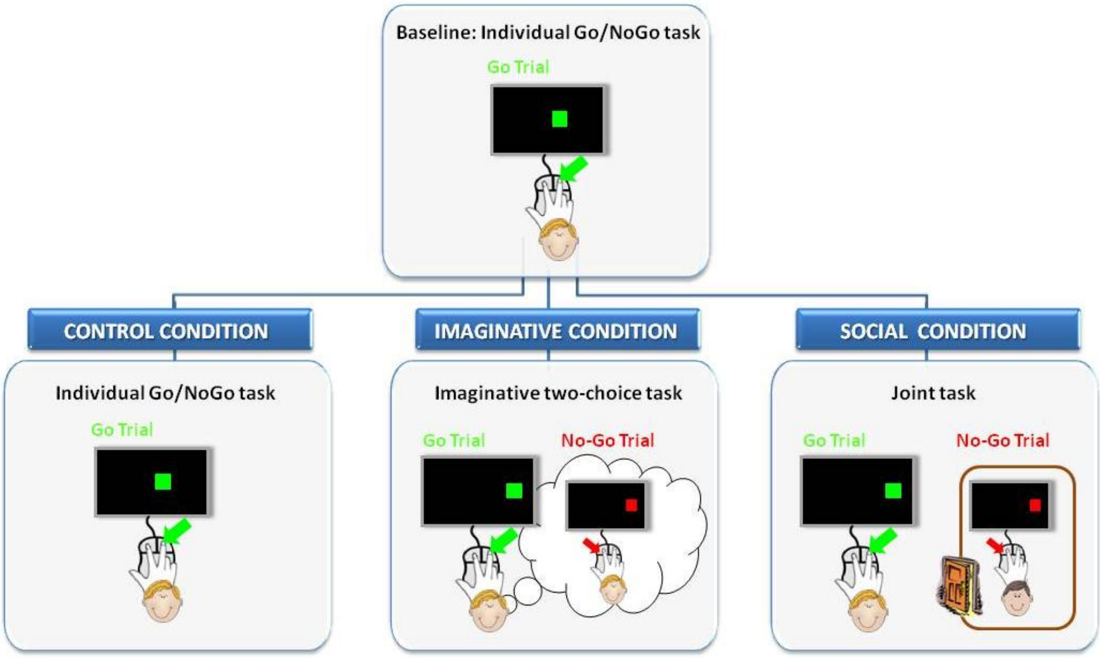

Figure 4.1. Schematic representation of the experimental design adopted in Experiment 4. Participants were randomly assigned to one of three experimental conditions: control, imaginative or social. Each experimental condition comprised two tasks (i.e., the baseline individual task and the critical task). Participants assigned to the control condition, after completed the baseline, simply continued to perform the same Go/NoGo task individually. Participants assigned to the imaginative condition, once completed the baseline performed a task requiring them to imagine responding to the complementary color. In contrast, participants assigned to the social condition, after the baseline, were required to perform the same Go/NoGo task with an alleged co-actor who was in a non-specified room and was thought to respond to the complementary color.

assigned to either the control or the imaginative condition, whereas 32 participants were assigned to the social condition. Each condition comprised two tasks: the baseline and the critical tasks. Conditions were defined as control, imaginative or social depending on the task that participants would have performed after the baseline: the repetition of the individual Go/NoGo task, the imaginative two-choice task and the joint task, respectively (see Figure 4.1).

4.2.1.2 Apparatus, stimuli and procedure

All participants seated about 57 cm from a 17-inch monitor screen and performed two tasks, with a 5-min break in between.

In all tasks, participants were instructed to press one of the two buttons of a computer mouse in response to stimuli of one color (Go color) and not to respond to stimuli of the other color (NoGo color). The mouse was aligned with the middle of the screen. Half of the participants responded with the left button, which was operated with the index finger of the right hand; the other half responded with the right button, which was operated with the middle finger of the right hand. The Go color and the response position were counterbalanced across participants and were kept constant in the two consecutive tasks. In the imaginative two-choice task, participants were also asked to imagine responding to the NoGo color, whereas in the joint task they believed that another person was responding to the NoGo color. Half of the participants were told that the co-actor was responding with their same button, whereas the other half were told that the co-actor was using the alternative button.

In all tasks, trials began with presentation of a central 0.8° × 0.8° white fixation cross, which remained visible for 500 ms. At the offset of fixation, the target stimulus (i.e., a 1.9° × 1.9° colored square) was presented for 300 ms. The target was shown either on the left or on the right of the fixation (the centre of the target was horizontally aligned with fixation, 5.7° to the left or right) and it could be either green or red. Both the fixation point and target were presented on a black background. Offset of the target was followed by a blank of 500 ms. Thus, on the whole the time allowed for a response was 800 ms. If the response was correct, the trial terminated with an additional 400-ms blank interval. In the case of an error (i.e., responses to the NoGo color, with the wrong button or with latencies in excess of 800 ms) a 200-ms visual error feedback (a string of six exclamation marks) was presented instead, followed by a 200-ms blank interval.

In the joint task, to stress the participant's feeling that another person was engaged, a *click* sound, randomly ranging from 240 to 622 ms, was delivered during the NoGo trials to signal the co-actor's response. Participants were also instructed to press their response button to inform the alleged co-actor that they were ready to initiate the experiment or a new block of trials. Afterwards, a *click* sound and the presentation of an "ok" message on the screen signaled to the participant that the co-actor was ready to start as well. The computer delivered this reply after a random time interval.

Each task consisted of 240 randomly mixed trials divided into two blocks. There were 120 Go trials and 120 NoGo trials. In half of the Go trials, stimulus and response positions corresponded, whereas, in the other half, stimulus and response positions did not correspond. Experimental trials were preceded by 8 practice trials.

4.2.2 Results

Error data (0.8%) were not analyzed. I first analyzed RTs for the baseline task. Correct mean RTs were submitted to an ANOVA with spatial correspondence (corresponding vs. noncorresponding) as within-subjects factor and two between-subjects factors: response button position (left- vs. right-button participants) and condition (imaginative vs. social vs. control). That allowed me to test the presence of differences between the three groups of participants in the baseline task. The analysis revealed a significant main effect of correspondence [$F(1,58)=21.97$, $p<.001$; $\eta_p^2=.28$]. Participants were faster in corresponding than in noncorresponding trials (332 vs. 340 ms). Response position was also significant [$F(1,58)=4,13$, $p<.05$; $\eta_p^2=.07$]: Left-button participants were faster than right-button participants (325 vs. 346 ms). More important, a significant Response position×Correspondence interaction was found [$F(1,58)=10.94$, $p<01$; $\eta_p^2=.16$]. Post-hoc analysis (Newman-Keuls) revealed that for right-button participants, responses were faster in corresponding than noncorresponding trials (340 vs. 353 ms, $p<.001$), whereas the two types of trials did not differ from each other for left-button participants (324 vs. 326 ms, $p=.56$). Condition did not yield a significant effect and did not interact with any other factors [all $Fs\leq1.96$, all $ps\geq.15$; all $\eta_p^2s\leq.06$].

Next, I analyzed the baseline and the critical tasks of each condition (see Figure 4.2).

Given the differences between left- and right-button participants observed in the baseline task, two separate ANOVAs were conducted for the two response positions. In

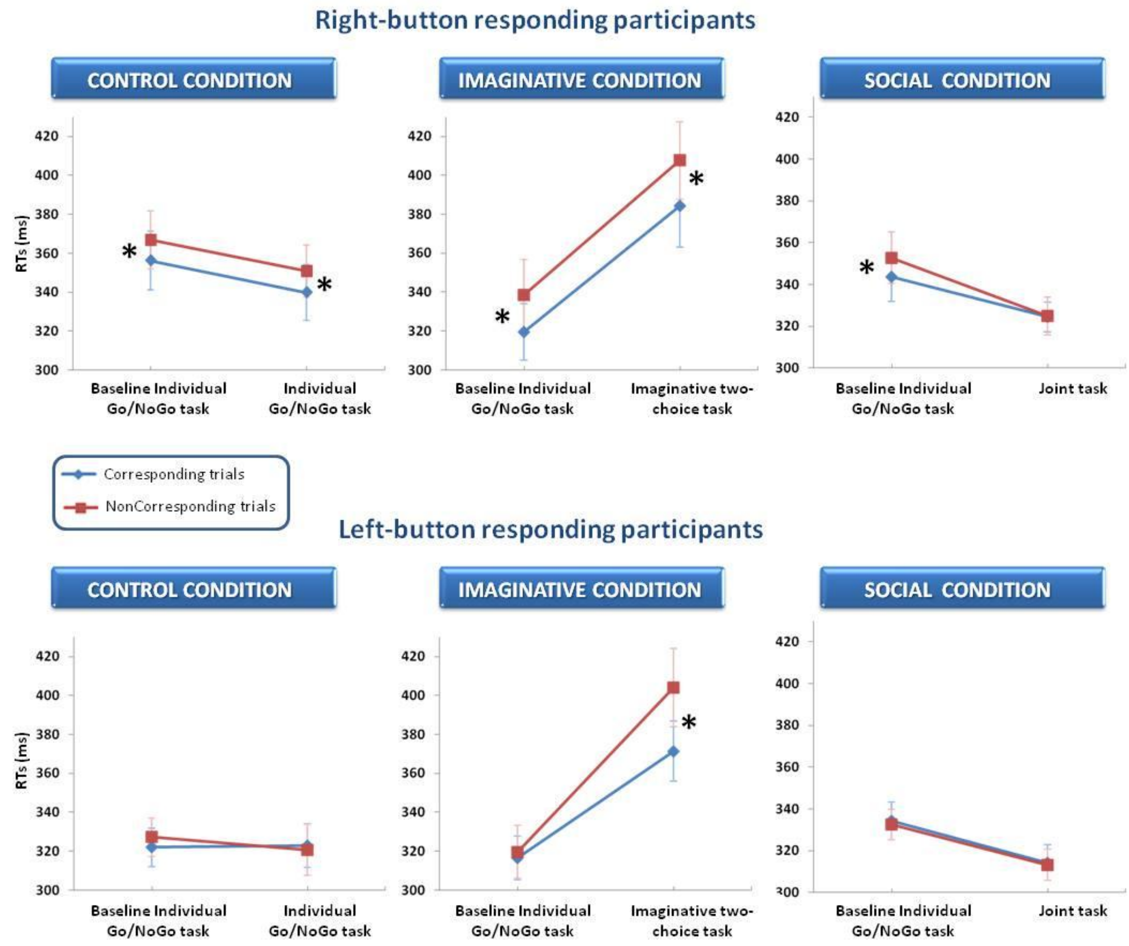

Figure 4.2. Means (± S.E.M.s) of correct RTs for each experimental condition in Experiment 4. For each condition, RTs are plotted as a function of response button position (left- vs. right-button participants), task (baseline vs. second task) and spatial correspondence (corresponding vs. noncorresponding trials). Asterisks indicate the presence of the Simon effect.

each ANOVA, there were two within-subjects factors: task (baseline vs. critical task) and correspondence (corresponding vs. noncorresponding). In the social condition, besides the two within-subjects factors, the co-actor's response position (same- vs. alternative-button) was included in the analysis as between-subjects factor. This latter factor did not have a significant effect and did not interact with any other variable [all Fs≤2.00, all ps≥.18; all η_p^2s≤.08].

The main effect of task was significant in both imaginative and social conditions and for both left- and right-button participants (all $Fs \geq 7.24$; all $ps < .05$, all $\eta_p^2 s \geq .34$), whereas it was never significant in the control condition. In the imaginative condition, participants were slower in the imaginative two-choice than in the baseline task (388 vs. 318 ms and 396 vs. 329 ms, for left and right-button participants, respectively). In the social condition, participants were faster in the joint than in the baseline task (314 vs. 333 ms and 325 vs. 348 ms, for left and right-button participants, respectively).

Correspondence was significant in all experimental conditions for right-button participants [all $Fs \geq 6.28$, all $ps < .05$, all $\eta_p^2 s \geq .31$]: A Simon effect of 21-, 5-, and 11-ms was found in the imaginative, social and control conditions, respectively. In contrast, for left-button participants, Correspondence was significant only in the imaginative condition, in which a 18-ms Simon effect was found [$F(1, 7)=12.62$, $p<.01$; $\eta_p^2=.64$].

In the imaginative condition, the Task×Correspondence interaction was significant only for left-button participants [$F(1, 7)=14.84$, $p<.01$; $\eta_p^2=.68$]. These participants showed no Simon effect in the baseline task ($p=.59$), whereas they showed a 32-ms Simon effect in the imaginative two-choice task ($p<.001$). In contrast, for right-button participants, the interaction was not significant: The Simon effect was present in both tasks (19-ms and 23-ms in the baseline and in the imaginative two-choice, respectively).

In the social condition, I found the opposite pattern of results. The Task×Correspondence interaction was significant only for right-button participants [$F(1, 14)=4.61$, $p<.05$; $\eta_p^2=.25$]. For these participants, corresponding trials yielded faster responses than noncorresponding trials in the baseline task (343 vs. 353 ms; $p<.001$), whereas there was no difference between corresponding and noncorresponding trials in the joint task (324 vs. 325 ms; p=.88). Conversely, for left-button responding participants, this interaction was not significant. The Simon effect was, indeed, absent in both tasks.

In the control condition, the Task×Correspondence interaction was never significant. Right-button participants exhibited an 11-ms Simon effect in both the baseline and the repetition of the individual Go/NoGo tasks, whereas left-button participants showed no effect in either tasks.

4.2.3 Discussion

The results observed in the baseline task of Experiment 4 showed that the Simon effect did not occur for left-button participants, suggesting that the task is appropriate to test whether the mere belief of co-acting with another person responding to the complementary color is sufficient to give rise to the Simon effect.

In contrast, the Simon effect was shown by right-button participants. This finding demonstrates that these participants also represented the left button (hence, they represented both left and right responses), although it was task irrelevant and it was not mentioned in the instructions. These participants were also slower than left-button participants, who presumably represented only the required response, thus preventing any competition between responses to slow down RTs. These results are consistent with previous findings demonstrating the role of both contextual factors and previous experience (here, the massive practice with the left mouse button in daily life) in determining the representation of two alternative responses in individual Go/NoGo tasks (Ansorge & Wühr, 2009, 2004). For this reason, the present finding represents an incremental contribution to the literature of the Go/NoGo Simon effect in showing that even a simple response device can induce participants to spatially code the alternative (non-requested) response, thus giving rise to the Simon effect (see also Dittrich et al., 2012).

More interestingly, participants' performance was critically modulated by the kind of task executed after the baseline. Notably, the instructions associated to the imaginative two-choice and to joint tasks gave rise to opposite effects. First of all, they had a specific and differentially impact on participants' RTs. Compared to the baseline task and regardless of the response button used to respond, RTs slowed down in the imaginative two-choice task, whereas the opposite trend occurred in the joint task. The significant increase of RTs in the imaginative two-choice task is consistent with previous findings showing that mentally performing an action is functionally similar to actually executing that action (e.g., Decety, & Grèzes, 2006; Decety, Jeannerod, & Prablanc, 1989). Thus, it is reasonable to assume that the imaginative two-choice task is functionally similar to the classical two-choice Simon task, in which the alternative response is effectively emitted[10]. This is further attested by the occurrence of the Simon effect in this task. Conversely, the significant reduction of RTs observed in the joint task is consistent with previous findings on the joint Simon effect (e.g., Sebanz et al., 2003) and it is thought to be triggered by an increased arousal induced by social

[10] Another possible explanation, however, is that the instructions associated with the imaginative two-choice task induced an extra-load on the working memory, making this task more demanding.

presence, which is typically the case on easy tasks (Guerin, 1993Aiello & Douthitt, 2001).

More importantly for the purpose of this study, the manipulations involved in the imaginative two-choice and in joint tasks, had an opposite influence on the size of the Simon effect. In the imaginative two-choice task, the explicit request of representing the alternative response made participants either to activate this representation (for left-button participants) or to keep it active (for right-button participants), allowing the Simon effect to emerge even when it had not occurred in the baseline task. Left-button participants – who did not exhibit any effect in the baseline task – showed the Simon effect, whereas right-button participants continued to show the same effect emerged in the baseline task. In contrast, the belief of co-acting with an unseen co-actor was ineffective in eliciting the Simon effect. In the joint task, left-button participants continued to show no difference between the two correspondence conditions, whereas for right-button participants the effect disappeared. The absence of the joint Simon effect is at odds with the results observed by Tsai et al. (2008) and Ruys and Aarts (2010). Most importantly, this finding is inconsistent with the assumption – underlying the action co-representation account – that sharing a Simon task with a co-actor, responsible for the complementary color, leads participants to spatially code the alternative response (the co-actor's action). Based on this account, indeed, the mere belief of co-acting with another individual, responsible for the complementary color, should have gave rise to Simon effect just like the explicit request to activate the representation of the alternative action. Instead, the absence of the joint Simon effect is in line with the referential coding account of the joint Simon effect in showing that the mere belief of co-acting with another person and the mere knowledge about the co-actor’s task are not sufficient to make participants representing the alternative action: When the co-actor in not physically present, the joint Simon effect does not show up.

Finally, another important result deserves attention: The joint instructions made the Simon effect to disappear for those participants who showed it in the baseline task (right-button participants). This result is particularly interesting because, since transfer effects from one task to the other are very common (Ansorge & Wühr, 2009, 2004), one would have expected to still observe the Simon effect in the group of participants who performed the joint task with the right button. The disappearance of the Simon effect cannot be traced back to a practice effect, as demonstrated by the results observed in the control condition. Indeed, right-button participants continued to show the Simon effect in the repetition of the Go-NoGo task. Thus, the mere repetition of the task does not cause the disappearance of the effect: Both the two responses were kept active in the second task, even without the explicit request of activating the alternative response.

The disappearance of the Simon effect may have been caused by a mere social facilitation effect (Huguet et al., 1999; Baron, 1986): The belief of co-acting with another individual might have induced participants to focus their attention on the relevant stimulus attribute (i.e., its color) and this might have reduced the interference effect of the irrelevant stimulus attribute (i.e., its position). If this were the case, the Simon effect should disappeared also when the co-actor is thought to respond to the same color of the participant.

However, an alternative hypothesis could be advanced. The disappearance of the Simon effect in the joint task of the present study could have been induced by a division of labor established between the participant and the co-actor, in like manner as task sharing made the semantic interference effect to disappear in Study 1.

It is possible that, when performing the baseline task, right-button-responding participants may have associated the left response with the complementary color. In the joint task, however, due to the belief that the actor was responding to the complementary color, these participants may have attributed to the co-actor also this alternative response, regardless of the response button used by the co-actor. Given that these participants had no clue about the spatial position of the co-actor, it is possible that the response associated to the co-actor may have lost its spatial connotation. As a consequence, only one response remained active in the participants' task representations, thus determining the disappearance of the Simon effect. If this were the case, than the Simon effect should persist both when the co-actor is thought to respond to the same color as the participant and when the co-actor is supposed to work on the complementary color but the participants know where the co-actor is. These possibilities were tested in Experiments 5 and 6, respectively.

4.3 EXPERIMENT 5

Experiment 5 aimed at excluding the possibility that the disappearance of the Simon effect observed in the joint task of Experiment 4 was simply due to a social facilitation effect. To this end, after completing the baseline task, participants executed a joint task identical to that of Experiment 4 except that they were told that the co-actor, who was in a non-specified room, was responding to their same Go color (i.e., joint task – same target color assigned to the co- actor; e.g., both the participant and the co-actor responded to the green color; see Figure 4.3).

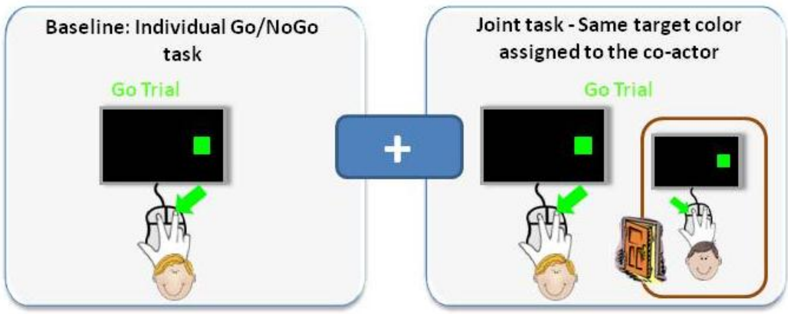

Figure 4.3. Schematic representation of the experimental design adopted in Experiment 5. After the baseline task, participants were required to perform the same Go/NoGo task with an alleged co-actor who was in a non-specified room and was thought to respond to their same color.

The following predictions can be made. First of all, I expect to replicate the pattern of results observed in the baseline tasks of Experiment 4: Only right-button participants should show the Simon effect in the individual Go/NoGo (baseline) task, whereas left-button participants should not any effect.

In the joint task, since the co-actor is thought to respond to the same target color of the participant, the Simon effect is not expected to occur for left-button participants (see Lam & Chua, 2010).

Importantly, for right-button participants a different pattern of results is expected on the basis of the social facilitation and the division-of-labor hypotheses. If the disappearance of the Simon effect observed in the joint task of Experiment 4 was due to a generic social facilitation effect, then the Simon effect should disappear also when the co-actor is thought to respond to the same target color of the participant. Indeed, according to the social facilitation theories, knowing that another person is involved in the task should lead participants, regardless of the co-actor's task, to focus their attention on the relevant stimulus information and to filter out the irrelevant stimulus information. In contrast, if in the joint task of Experiment 4 the Simon effect disappeared because the co-actor was responding to the complementary color, then the Simon effect should persist when the co-actor responds to the same target color of the participant. In this case, indeed, a division-of-labor cannot come into play.

4.3.1 Method

4.3.1.1 Participants

Thirty-two undergraduate students of the University of Trento (5 males; aged 19 – 27 years; all right-handed) participated in the experiment. All participants were not aware of the purpose of the experiment, they did not participate in the previous experiments and they had a normal or correct-to-normal vision.

4.3.1.2 Apparatus, Stimuli and procedure

The apparatus, stimuli and procedure were as in the social condition of Experiment 4 with the following exceptions. After the baseline task, participants performed a joint task in which they believed that the co-actor was performing their same task (i.e., s/he was responding to their same Go stimuli). The *click* sound signaling the co-actor's response was delivered at the end of the Go trials, 800 ms after Go stimulus presentation. Participants were told that the *click* sound did not correspond in time to the co-actor's response - given that it might have overlapped to their response - and that it was emitted only to inform them whether the co-actor had responded or not.

4.3.2 Results and discussion

Error data (0.5%) were not analyzed. Correct mean RTs of left- and right-button participants were submitted to two ANOVAs with the same factors of the social condition of Experiment 4. Again, the co-actor's response position did not have any effects.

Task was significant for both left and right-button participants [both Fs≥7.02, both *p*s<.05, both η_p^2s≥.33]. Consistently with the pattern of results observed in the social condition of Experiment 4, RTs were faster in the joint than in the baseline task (331 vs. 340 ms and 321 vs. 340 ms, for left- and right-button participants, respectively).

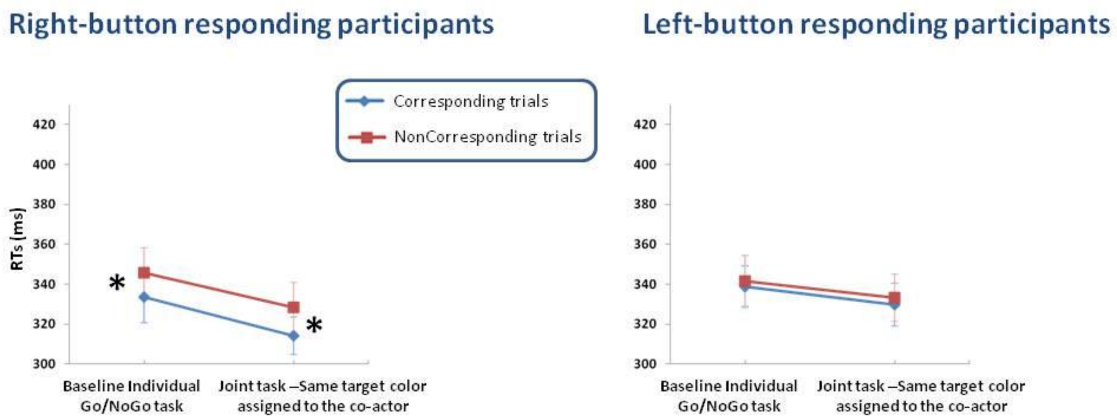

Figure 4.4. Means (± S.E.M.s) of correct RTs for right- and left-button responding participants in Experiment 5. RTs are plotted as a function of task (baseline vs. joint task) and spatial correspondence (corresponding vs. noncorresponding trials), separately for the two response button positions (right- vs. left-button participants). Asterisks indicate the presence of the Simon effect.

Correspondence was significant only for right-button participants, [$F(1, 14)=38.34$, $p<.001$; $\eta_p^2=.73$]: Responses were faster in corresponding than noncorresponding trials (324 vs. 337 ms).

The Task×Correspondence interaction was never significant (see Figure 4.4).

Left-button participants exhibit the Simon effect neither in the baseline nor in the joint tasks: The difference between noncorresponding and corresponding trials was 3 and 4 ms in the baseline and in the joint tasks, respectively. Conversely, right-button participants showed a Simon effect in both tasks: A corresponding trials advantage of 13 and 14 ms was observed in the baseline and in the joint task, respectively.

Consistently with the results observed in Experiment 4, only right-button participants showed the Simon effect in the baseline task of this experiment. Most importantly, the results of Experiment 5 demonstrate that when participants perform the joint task with another individual who is thought to respond to their same Go color, the belief of co-acting with another individual has no influence on their performance: Participants behave as if they were still performing the Go/NoGo task individually. These results are inconsistent with the social facilitation hypothesis and support the division-of-labor account: When a division-of-labor is hampered, right-button participants do show a Simon effect in the joint task as well. This latter result suggests that for these participants the representation of the left mouse button, which automatically seems to occur in the baseline task, was still active during the joint task, being the complementary color not associated to any other person.

4.4 EXPERIMENT 6

Experiment 6 aimed at verifying the hypothesis that the absence of any information about the position of the co-actor may have caused the alternative response to lose its spatial connotation after attributing it to the co-actor. To this end, after completing the baseline task, participants performed a joint task identical to that of Experiment 4: They were told that the co-actor was responding to the complementary color. However, in contrast with the joint task of Experiment 4, participants were also informed the co-actor was acting in a room that was located on the opposite side relative to their response button (e.g., if the participant had to respond by pressing the left button, s/he was told that the co-actor was in the room on his/her left). The position of the room in which the co-actor was supposed to act coincided always with the position of the co-actor's response button (e.g., if the co-actor was acting in the room on the left, s/he was responding with the left mouse button; see Figure 4.5).

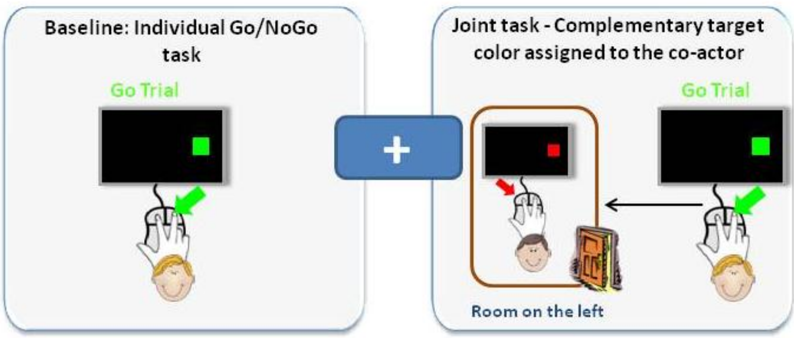

Figure 4.5. Schematic representation of the experimental design adopted in Experiment 6. After the baseline task, participants were required to perform the same Go/NoGo task with an alleged co-actor who was thought to respond to the complementary color. Participants were also told that the co-actor was performing his/her part of the task in the room spatially opposed to their response position. The co-actor's response button position corresponded always to the position of the room in which s/he was thought to act.

Consistently with Experiments 4 and 5, right-button participants should show the Simon effect in the baseline task, whereas left-button participants should not.

Instead, the following predictions can be made for the joint task. If the information about the co-actor's position is sufficient *per se* to determine the representation of the alternative response, left-button participants should show the Simon effect. Conversely, if this information is not sufficient, no effect is expected for these participants.

For right-button participants I expect that the information about the co-actor's position may allow the alternative response to keep its spatial connotation even after attributing it to another person. If this were the case, the Simon effect should persist in the joint task.

4.4.1 Method

4.4.1.1 Participants

Sixteen undergraduate students of the University of Trento (all females; aged 19 – 24 years; all right-handed) participated in the experiment. All participants were not aware of the purpose of the experiment, they did not participate in the previous experiments and they had a normal or correct-to-normal vision.

4.4.1.2 Apparatus, Stimuli and procedure

The apparatus, stimuli and procedure were as in the social condition of Experiment 4 with the following exceptions. Participants were told that the co-actor was performing his/her part of the task in the room spatially opposed to their response button position.

Furthermore, the co-actor was thought to respond to the complementary color by pressing always the alternative mouse button (e.g., if the participant responded by pressing the right button, the co-actor was thought to use the left one). The co-actor's response button position coincided with the position of the room in which s/he was supposed to act.

4.4.2 Results and discussion

Error data (0.1%) were not analyzed. Correct mean RTs of left- and right-button participants were submitted to two ANOVAs with two within-subjects factors: task (baseline vs. critical task) and correspondence (corresponding vs. noncorresponding).

Task was significant for both left and right-button participants [both Fs≥6.95, both *p*s<.05, both η_p^2s≥.50]: RTs were faster in the joint than in the baseline task (312 vs. 351 ms and 322 vs. 334 ms, for left- and right-button participants, respectively).

Correspondence was significant only for right-button participants, [$F(1, 7)=18.35$, $p<.005$; $\eta_p^2=.72$]: Responses were faster in corresponding than noncorresponding trials (322 vs. 334 ms).

The Task×Correspondence interaction was never significant (see Figure 4.6).

The results of the baseline tasks of Experiment 6 replicate those observed in the baseline tasks of previous experiments described in the present study. The Simon effect occurred in this task only for right-button participants. Left-button participants did not show any effect.

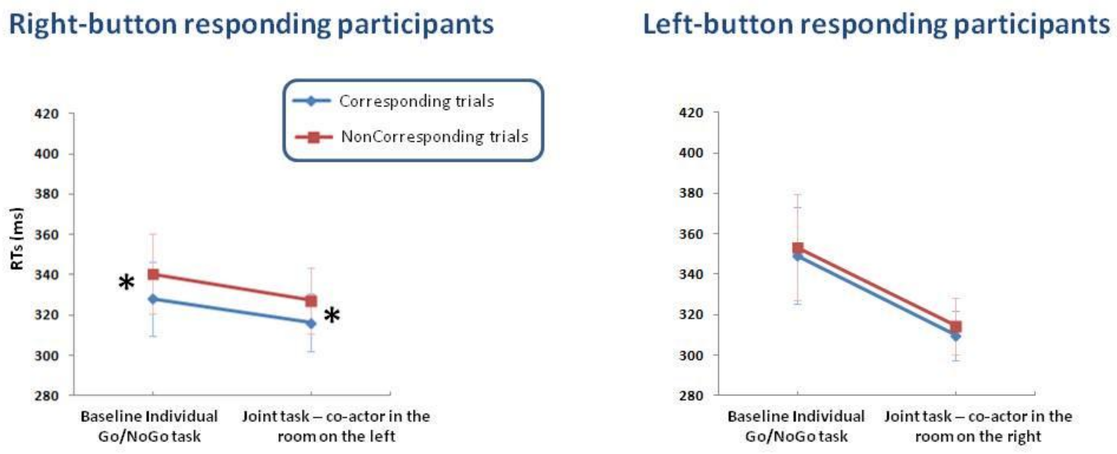

Figure 4.6. Means (± S.E.M.s) of correct RTs for right- and left-button responding participants in Experiment 6. RTs are plotted as a function of task (baseline vs. joint task) and spatial correspondence (corresponding vs. noncorresponding trials), separately for the two response button positions (right- vs. left-button participants). Asterisks indicate the presence of the Simon effect.

In the joint task, left-button participants continued to show no effect. The absence of the Simon effect in the joint task of these participants extends the results observed in the joint tasks of Experiments 4 and 5: Besides confirming that the belief of co-acting with another person – responsible for the complementary color – is not sufficient to give rise to the Simon effect when the co-actor (i.e., the alternative action) in not physically present, it demonstrate that the information about the co-actor's position is useless as well. Importantly for the purpose of this experiment, for right-button participants the Simon effect continued to be present in the joint task. This finding confirm the hypothesis that the disappearance of the Simon effect observed for these participants in the joint task of Experiment 4 was due to the fact that the assignment of the alternative response to another person without having any information about his/her position makes this response to lose its spatial connotation. Indeed, when participants know where the co-actor is, as happened in the joint task of this experiment, the Simon effect persists, thus suggesting that the response associated to the complementary color (i.e., to the co-actor's task) remains active in the participants' task representation. Furthermore, this finding suggests that the presence of the Simon effect in the joint task of Tsai's et al. (2008) study is probably due to the fact that participants knew the position of the room in which the co-actor was acting.

4.5 GENERAL DISCUSSION

The aim of the present study was to shed light on the mechanisms underlying the joint Simon effect by assessing whether sharing a Go/NoGo Simon task with another person responsible for the complementary color can induce the Simon effect even when the co-actor perform his/her part of the task in a different room. The results of three experiments provide converging evidence showing that, when the co-actor is not physically present, the mere information about the co-actor's task is not sufficient to allow participants representing the alternative response, thus to give rise to the Simon effect. Indeed, left-button participants showed this effect neither in the baseline nor in the joint task. This finding, besides failing to replicate earlier results by Tsai et al. (2008) and Ruys and Aarts (2010), supports the referential coding account of the joint Simon effect: When the co-actor is not physically present, the Simon effect does not show up. Thus, it is reasonable to assume that the occurrence of the joint Simon effect in previous studies has been very likely due to the fact the co-actor *per se* may represent an alternative action, when acting next to the participant.

However, it must be said that the results of the present study are not completely at odds with the action co-representation account. I observed that knowing the co-actor's task can have a specific impact on participants' performance. In the social condition of Experiment 4, indeed, the belief of co-acting with another individual, who was responding to the complementary color, made the Simon effect to disappear for those participants who have shown it in the previous baseline task. As previously discussed, the occurrence of the Simon effect in this task is probably due to the fact that these participants represented the left button because of the familiarity with the mouse. Hence, task sharing caused the disappearance of the interference effect produced by the (incidental) spatial representation of an alternative response (the left response). To account for this finding, I proposed that, in the baseline task, right-button participants have associated the left response to the complementary color. Afterwards, since in the joint task the complementary color was up to the co-actor, participants have attributed to the co-actor also this response. However, as participants did not have any information about the co-actor's position, the left response might have lost its spatial connotation, thus causing the disappearance of the Simon effect.

This hypothesis was supported by the results of Experiments 5 and 6: Right-button participants continued to show the Simon effect in the joint task both when the co-actor was thought to respond to their same color (in Experiment 5) and when s/he was thought to respond to the complementary color but participants knew where the co-actor was (in Experiment 6). The presence of the Simon effect in the joint task of Experiment 5 would demonstrate that when the co-actor is working on the same color of the participant, the alternative response remains active in participants' task representation just because it cannot be attributed to anyone else. Whereas the presence of the Simon effect in the joint task of Experiment 6 would demonstrate that even if the co-actor is working on the complementary color, the information about his/her position does not allow the alternative response to lose its spatial connotation.

5

General discussion

The aim of this thesis was to examine whether and to what extent performing a task with another person may change individual cognitive performance. As previously stated, interference paradigms are particularly suitable to address this issue, as they allow understanding how people can deal with the task irrelevant information when the accomplishment of a task is achieved in a joint and cooperative context.

However, studies using different kinds of joint interference paradigms are not consistent in their results. Studies employing the joint version of Simon-like paradigms provided evidence showing that, in joint tasks, participants represent the co-actor's task to such an extent that performance is affected as if they were performing the partner's task as well (Atmaca et al., 2011, 2008; Sebanz et al., 2003). This leads participants to show interference effects that do not usually occur when they perform the same task without the co-actor. Yet, the fact that an interference effect unavoidably occurs whenever two individuals work together on the same task was brought into question by a recent study (Heed et al., 2010) showing that in joint tasks participants can ignore the co-actor task. This leads to a facilitation effect instead of producing (or increasing) interference.

After examining the peculiarities of the joint paradigms, I proposed that the different nature of these tasks can account for the contrasting results. In particular, I hypothesized that interference effects can occur when the actor and the co-actor perform two complementary tasks, working on two different values of the same stimulus; on the contrary a facilitation effect (i.e., a reduction of interference) is expected when they have to execute simultaneously two independent tasks on two different stimuli. The rationale behind this hypothesis was the following: If the co-actor works simultaneously on the stimuli that cause interference, task sharing could lead the participant to ignore these stimuli, thus leading to a reduction of the interference effect. Conversely, when two participants work on two different values of the same target stimulus, not only the complementary value cannot be easily ignored but it is also very likely that the alternative response associated to it can be activated, thus leading to interference produced by the activation of the two alternative responses.

In Study 1 (Experiments 1, 2 and 3) I tested this hypothesis by having participants perform the PWI paradigm (Rosinski et al., 1975), which requires to name a picture while ignoring a distractor word, both individually (baseline task) and co-acting with an alleged partner (joint task). The results of this study confirmed my hypothesis. Results showed that, compared to the baseline task and to a control condition in which participants continued to perform the PWI individually, the belief of co-acting with another individual suppressed the semantic interference effect when the co-actor was thought to be in charge of the distractor stimuli. To account for this finding I proposed that the belief that another person was working on the distractor stimuli allowed participants to succeed in ignoring these stimuli, thus preventing the semantic interference effect to occur.

The social manipulation, however, was effective only when written word recognition was delayed or impaired by case alternation (Experiments 2 and 3). In Experiment 1, in which distractor stimuli were shown in upper case letters, written word recognition is so mandatory that participants fail to ignore the distractor stimuli.

The results of Experiments 3 further supports the hypothesis that the disappearance of the semantic interference effect is strictly related to the fact that the co-actor is thought to work on a different stimulus. Indeed, sharing a PWI paradigm with a co-actor working on the same stimuli as the participant (i.e., both the participant and the co-actor responded to the picture) did not eliminate the semantic interference effect.

Overall, the results of Study 1 seem to confirm that the occurrence of interference or facilitation effects in joint paradigms depends on the nature of task distributed between two participants: Interference effects occur when the actor and the co-actor work on different values of the same target stimulus, whereas facilitation effects occur when the two participants are in charge of different stimuli.

In Study 2 (Experiments 4, 5 and 6) I employed the Go/NoGo version of the Simon task (Simon & Small, 1969) to assess whether the occurrence of the interference effect in joint Simon tasks (Sebanz et al., 2003) really reflects the representation of the co-actor's task. To this end, in Experiment 4 participants performed a Go/NoGo Simon task first individually (baseline), and then either imaging themselves responding to the NoGo stimuli (imaginative two-choice task) or co-acting with another person who was in a non-specified room and was thought to respond to the complementary color (joint task). The rationale behind this experimental design was the following. If the information about the co-actor's task is sufficient to allow participants activating the representation of the alternative response associated to the complementary color, participants engaged in the imaginative two-choice and in the joint tasks should show the same pattern of results: The Simon effect for both groups as compared to the baseline task.

Yet, the results contradicted this expectation. Compared to the baseline task and to a control condition in which participants continued to perform the Go/NoGo Simon task individually, while the instructions associated to the imaginative two-choice task made the Simon effect to occur, those associated to the joint task were ineffective in eliciting the Simon effect. The absence of the Simon effect in the joint task supports the referential coding account of the joint Simon effect (Dolk et al., 2013) in showing that when the co-actor is non-physically present, the alternative response is not represented. This finding is at odds with the assumption – underlying the action co-representation account (Sebanz et al., 2006) – that knowing that the co-actor is performing the complementary task leads participants to activate the alternative response associated to this task.

Besides that, the results of Experiment 4 demonstrated that the belief to perform the task with another person in charge of the complementary task made the Simon effect to disappear for those participants who have shown it in the previous baseline task. To account for this result I proposed that the belief that someone else was taking care of the NoGo stimuli allows participants to attribute to the co-actor also the alternative response that they have previously associated to these stimuli. However, given that no information about the co-actor’s position was provided to the participants, this response lost its spatial connotation. This hypothesis was supported by the results of Experiments 5 and 6: In the joint task, the Simon effect continued to be present in the joint task both when the co-actor was thought to perform the same task as the participants (i.e., both the participant and the co-actor responded to the same color; in Experiment 5) and when participants knew where the co-actor was even if, as in Experiment 4, s/he was thought to respond to the complementary color (in Experiment 6). The persistence of the Simon effect in the joint task of Experiment 5 is consistent with the hypothesis that when the co-actor works on the same stimuli as the participant, the alternative response cannot be attributed to anyone else and, consequently, it remains active in participants' task representation. Whereas the persistence of the Simon effect in the joint task of Experiment 6 supports the hypothesis that when the spatial information about the co-actor's position is provided, this information makes the alternative response to keep its spatial connotation even after attributing it to another person.

On the whole, the results of Study 2 contribute to the debate on the mechanisms underlying the joint Simon effect by providing further evidence supporting the referential coding account of this effect. Furthermore, the results of this study are consistent with the action co-representation account in showing that the information about the co-actor's task can influence participants' performance.

Importantly, the results of Study 2 extend the findings of Study 1 to the conditions in which the actor and the co-actor work on two complementary values of the same stimulus. Indeed, in both studies and regardless of the paradigm used, I observed that task sharing can determine the disappearance of the interference effect produced by the task irrelevant information (Study 1) or by the (incidental) spatial representation of an alternative response (Study 2). The disappearance of the interference effects, however, occurs only when the co-actor was thought to work on different or complementary stimuli but not when s/he was in charge of the same stimuli as the participant. This allows ruling out the hypothesis that the suppression of the interference is due to a generic social facilitation effect induced simply by the involvement of another individual (cf. Huguet et al., 1999). Instead, the disappearance of the semantic interference effect as well as of the Simon effect seems to be triggered by the implementation of a division-of-labor strategy between the actor and the co-actor, which is an important component of social interactions. Indeed, "for shared representations of actions and tasks to foster coordination rather than create confusion, it is important that agents also be able to keep apart representations of their own and of others' actions and intentions. Unless it is clear who is doing (or preparing to do) what, coagents cannot efficiently plan their next moves" (Pacherie, 2011, p. 359).

Finally, the results of both studies, besides demonstrating that the mere belief of co-acting with another person is sufficient to modulate interference effects, converge in showing that task sharing can be effective in suppressing the interference effects only under certain circumstances. Task sharing can eliminate the semantic interference effect only when written word recognition is made more difficult; whereas the Simon interference effect can be suppressed only when participants are not informed about the position of the co-actor.

To conclude, recent studies demonstrated that it is possible to eliminate well-known interference effects by hypnotizing participants to make them ignoring the task irrelevant information (Lifshitz, Aubert-Bonn, Fischer, Kashem, Raz, 2013; Raz & Campbell, 2011; Iani, Ricci, Gherri, & Rubichi, 2006; Raz, Kirsch, Pollard, & Nitkin-

Kaner, 2006; but see Augustinova & Ferrand, 2012). The results of this thesis proved that this expensive and complex procedure is absolutely not necessary.

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