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SOCIAL COGNITION: NEW INSIGHTS FROM AFFORDANCE AND SIMON EFFECTS

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Ai miei genitori e

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INTRODUCTION

In the following pages, I would like to present my doctoral thesis giving an overview of the treated issues.

In Chapter 1, I have tried to contextualize the present project within the area of cognitive science. Specifically, the perspective of the present project can be inscribed within that endorsed by that area of cognitive science that in the last years moved from a focus on individual mind and on individual cognitive processes toward the need to consider the human ability to act in social contexts. Several findings supporting this view have been presented with the special aim of showing how researchers have noticed the need to retrieve the importance of the brain, body, and environment. Thus, an important change is taking place in the so-called “Social Cognition” framework, from a focus on the individual mind toward embodied and participatory aspects of social understanding. I have explored the origin and the recent development of a new interdisciplinary attempt, which combines approaches from various disciplines and integrates data from different levels of analysis: the social cognitive (neuro)science.

A relevant point for social cognitive (neuro)science, and for my thesis, is the notion of close perception-action link, as suggested by ideomotor theories. The idea that perception and action are tightly interwoven has received a growing attention also due to converging neurophysiological evidence on the so-called mirror or shared-circuit mechanism, which could provide the first unifying perspective of the neural basis of social cognition and of simulation mechanisms, linking first- and third-person experiences. In fact throughout the chapter it has been explained that the understanding of basic aspects of social cognition depends on activation of neural structures normally involved in our own personally experienced actions or emotions. By means of this activation, a bridge is created between the others and ourselves. With the sensory description of the observed social stimuli, internal representations of the state associated with these actions or emotions are evoked in the observers, “as if” they were performing a similar action or experiencing a similar emotion. Some relevant issues of social cognition have been then introduced, such as imitating action, joint action, motor resonance, emotional contagion, empathy, and theory of mind.

Among these topics, the aim of the present project was to shed more light on motor resonance and joint action, themes that have been detailed and discussed in the first and in the second part of the thesis, respectively. Each part has been organized so that each issue has been first treated both at a theoretical and empirical level, and then experimentally investigated in a series of experiments, by using two well-known effects of cognitive psychology: “Affordance” and “Simon”.

In the first part of this project, the Affordance effect has been considered.

In particular, in Chapter 2 the notion of affordance was discussed starting from the original theorization of Gibson who defined affordances as properties in the environment that are relevant for an organism’s goals and that provide the observer with practical opportunities which he/she is able to perceive and use. To clarify what type of properties affordances are, some post-Gibson theorizations were presented ranging from the position of those who stated that affordances are dispositional properties of the environment that must be integrated with some dispositional properties of individuals, to other that posited that they are relations between the features of a situation and the abilities of an individual. Particular attention has received the notion of “Micro-affordance” proposed by Ellis and Tucker to refer to the potential elements of an action. Micro-affordances have been defined as brain representations of action possibilities, namely as the result in the brain of the connection between visual responses and action-related responses and of previously stored perception-action experiences. Moreover, micro-affordances were intended as the relations between features of situations and individual abilities, and such relational nature was confirmed by several empirical findings obtained with behavioral, neurophysiological, and neuroimaging techniques. Such studies, of which I provided a brief overview, revealed that canonical neurons seem to have the role of representing objects as potential action patterns, thus representing the neural basis of affordances, and that objects observation can activate a motor simulation and overt movements. Then, an original research has been presented in order to illustrate how it is possible to empirically investigate the notion of affordance using a methodology of cognitive psychology. Specifically, the work explored whether information on object consistence is automatically activated in adults by measuring the participants' response times across different categorization tasks and different response modalities. A final section has been dedicated to the first topic of social cognition investigated in the present work, namely the motor resonance. Some findings have been presented to demonstrate how our brain "resonates" when we see others performing actions, and to point out that this resonance mechanism is modulated by the similarity between the actions we observe and the actions we are able to perform and is tuned to one's own motor capabilities. This theoretical and empirical overview allows us to understand how it can be possible to use the affordance effect to investigate the issue of motor resonance.

In Chapter 3 a first study with a twofold aim was presented. First, I investigated motor responses to objects and sensitivity to fine object characteristics (i.e., object typology and object category) and I verified how such responses develop. Specifically, I explored both in adults and school-age children the influence of a micro-affordance that can be defined dangerousness, namely the ability to differently perceive and process objects that can be potentially source of danger or pain for us (dangerous object) and objects that we can approach and interact without any risk (neutral object). Moreover, the capacity to discriminate between artefacts and natural objects was also investigated.

Second, I explored how motor resonance develops. Indeed, this issue concerns whether both children and adults are sensitive to the affordances and the potential dangers offered by the objects in the environment to others, so I measured if a general motor resonance phenomenon occurred or if this motor resonance effect was sensitive to fine-grained aspects. In fact, the study focused on the resonant mechanisms elicited when observing somebody actively preparing an action toward an object. I explored these issues with a priming paradigm, when the interaction between the hand and the object is not direct but potential, investigating at a functional level the mechanisms occurring during observation of a prime, given by a hand or by a control object, followed by objects that might be dangerous or provoke pain. Interestingly, the choice of a priming paradigm allowed to investigate the timing of two possibly involved mechanisms: one possibly related to the activation of the mirror neuron system, triggered by the observation of the prime-hand, and the other to the canonical neuron system, triggered by the presence of the object.

In the second part of the thesis I focused on the Simon effect.

In particular, in Chapter 4 I started with the presentation of the "stimulus–response (S–R) compatibility effect", used to investigate the link between systems for perception and action, and considered as a function of the relative locations of stimulus and response, to introduce the "Simon effect". This phenomenon, described for the first time in a seminal work of Simon and Rudell, refers to the finding that responses are faster and more accurate when correct response and stimulus location correspond than when they do not, even when stimulus location is an irrelevant feature to the task. Contemporary accounts widely assume that the Simon effect is due to a conflict, emerging at the stage of response selection. Particular attention has been dedicated to most recent studies on the so-called "social or joint Simon effect", namely to the finding that a similar Simon effect emerged even when the Simon task was shared between two participants. This evidence shows that each participant represented the stimulus-response rules and the action plans of both involved individuals and integrated this representation in his/her action planning. Such evidence is interpreted as an automatic emergence of shared representation. Starting from the work of Sebanz and colleagues, such joint effect has been used as a tool to investigate a relevant topic of social cognition, the joint action, and different cognitive processes related to it, such as perception, attention, action planning, and cognitive control. From the early data, many questions are been raised, concerning for example the cognitive and neural mechanisms underlying shared task representations and, more relevant to the present work, the social modulations, namely the influence of social variables on the creation of shared representations. In a final section the reviewed empirical findings has been discussed in a wider theoretical perspective on joint action. Focusing on a psychological approach, the mechanisms and a "minimal architecture" model that support joint action have been presented, as well as a classification of such actions giving a particular relevance to shared task representation process.

In Chapter 5, the second study started from some findings, reviewed in the previous chapter, which indicate the possible influence of social factors on the processes underlying joint actions and shared representation. Indeed, the second study of the thesis was aimed at investigating whether shared representations, as indexed by the presence of the joint Simon effect, are modulated by group membership. Specifically, considering some evidence and paradigms of social psychology, I explored the influence of two social variables on the emergence of shared representations. First, I investigated the role of minimal ingroup–outgroup distinctions: I manipulated minimal cues, dividing arbitrarily participants in two groups, and I measured their performance when a Simon task was executed with an individual who was supposed to belong to the same group or to a different group. Second, I manipulated a more complex ingroup–outgroup distinction, namely the role of experienced interdependence between participants, manipulating whether the goals of two jointly acting individuals were positively related and thus they had to cooperate during the joint Simon task, or whether they were negatively related and thus they had to compete during the task.

The study presented in Chapter 6 was closely related to the investigation presented in the previous chapter, as it was aimed to extend knowledge on the cognitive mechanisms at the basis of shared representations. Indeed, I further assessed whether shared representations are influenced by group membership, in particular by the interdependence experienced by two individuals. Specifically, considering some findings of social psychology and combining two paradigms of cognitive psychology, the joint Simon and the joint transfer-of-learning, I explored to what extent prior experience could modulate performance in task sharing. First I assessed whether performing a competitive or a cooperative practice task with another participant shaped the way a subsequent task was executed, comparing the participants' performance before and after the introduction of a condition of interdependence, and second I measured the duration of this potential effect.

Finally, a general discussion of the three studies has been presented to summarize the results obtained in the experiments conducted, emphasizing their original contribution and their importance within the Social Cognition research.

CHAPTER I

SOCIAL COGNITION

1.1 Cognitive Science: from an individualistic to a social perspective

Traditional cognitive science is born and grown by focusing on individual cognitive processes and taking into account the so-called "computer metaphor". The underlying idea of the computational metaphor is that of a "mind-software", namely the mind seems to be governed by programs or sets of rules analogous to those which govern computers and it could be understood without taking into account the brain, the body as a whole, and the environment (Neisser, 1976). In fact, "the task of ... trying to understand human cognition is analogous to that of … trying to understand how a computer has been programmed" (Neisser, 1967, p. 6). This analogy is chosen because a computer program is a "recipe for selecting, storing, recovering, combining, outputting and generally manipulating information" (Neisser, 1967, p. 8). As the computer operates computationally, so it seems does the human mind. According to this perspective, psychology can be considered "the study of the various computational processes whereby mental representations are constructed, organised, interpreted and transformed" (Boden, 1988, p. 5).

I will not get into this discussion, since the point that I would to emphasize is that in the current cognitive science emerges the need to retrieve the importance of the brain, body, and environment, in order to study more fully the mind and the cognitive processes. Indeed, researchers have noticed the need to consider the human ability to act in social contexts, where each other's actions and their consequences on the environment need to be taken into account. Just think about the crucial importance of the ability to correctly interpret social signals to predict future actions, and to coordinate one's actions with those of others in order to survive. As will be more fully explained later, one key process supporting this ability is the formation of shared representations both of what we and the others perceive, and of actions and tasks. This allows individuals to anticipate others' actions rather then simply responding to them and to flexibly interact in a changing environment.

In cognitive science, a general framework has been adopted to investigate perception, action, and cognition in social contexts. This framework favours a view, the so-called embodied cognition view, that incorporates motor aspects in perception, and emphasized the continuity and the exchanges between perception and action. Several researches underlines the close link between the so-called "low-level" or sensorimotor processes and the so-called "high-level" or cognitive processes. According to this perspective, cognition is embodied and grounded, namely cognition is influenced by our previous experiences, and it is related and constrained to specific physical characteristics of our body and of our sensorimotor system. This perspective is at odds with classical cognitivist view, which claims that mind is a tool for manipulating arbitrary symbols (e.g., Glenberg, 1997; Barsalou, 1999; for a review, see Barsalou, 2008).

Even if for a while perception and action have been extensively studied by assuming that they can be completely investigated by focusing on single individuals, in the last years in several researches areas, ranging from cognitive neuroscience to experimental and developmental psychology, and to philosophy, seems to emerge the need to adopt a new social perspective on perceptual, motor, and cognitive activities. Indeed, recently several works have been dedicated to explore both the neural and cognitive processes underlying basic social phenomena. Only to give some examples, have been considered phenomena such as joint attention (Campbell, 2002; Tomasello & Haberl, 2003; Eilan, 2005; Heal, 2005) and joint action (Knoblich & Jordan, 2002, 2003; Tomasello, Carpenter, Call, Behne, & Moll, 2005; Carpenter, 2009). More precisely, researchers have begun to investigate how low-level sensorimotor mechanisms of sharing attention and action are useful for joint attention and action, and how they influence the ability to act jointly, with the contribution of higher-level processes such as memory and mind-reading (Sebanz, Bekkering, & Knoblich, 2006a; Knoblich & Sebanz, 2008).

Unlike other animal species, human beings use language and abstract thinking, make calculations, and are able to develop tools. Larger brains enable humans to perform all kinds of cognitive operations (i.e., memory, learning, and perceptual processing) more efficiently than other species. However, the emergence of these capabilities cannot be understood without considering the demands of social interaction (e.g., Tomasello et al., 2005; Tomasello & Carpenter, 2007; Knoblich & Sebanz, 2008). In particular, humans appear to have a special motivation to share mental states and are able to flexibly coordinate their actions to reach common goals. The so strong human capability to cope with an unstructured world is also due to the ability to represent the actions and intentions of self and the others. For these reasons, the ability to form shared representations is a key factor for flexibly cope with a changing environment and, consequently, the cognitive mechanisms supporting the formation of shared representations is an increasingly relevant issue in psychology and neuroscience. This example clearly demonstrates that the interest for the social aspects has spread even to the “hard ”cognitive processes, traditionally considered as impermeable to the social aspects, such as attention. Indeed, in this field there is an increasing interest for the cognitive mechanisms involved in the creation of shared representations. This topic will be resumed below (see section 1.5.2), will be more thoroughly detailed in Chapter 4, and will be the focus of two experimental studies that I have conducted (Chapters 5 and 6).

1.2 Social Cognition: toward a definition

In the last few years the social dimension has obtained an increasing importance in most disciplines that fall under the label of “cognitive science” and “cognitive neuroscience”. Only recently researchers have begun to explore the biological basis of our social abilities and their evolution (Adolphs, 1999; Ochsner & Lieberman, 2001). For more than a century, social psychologists have investigated social behaviour, but their researches were conducted in isolation from the rest of neurobiology. Instead, the recent link between social psychology and neurobiology derives from studies about the “social brain” (Brothers, 1990; Dunbar, 1998; Frith & Frith, 2010). This social brain, for humans at least, has a “theory of mind”, which has a fundamental role in predicting others’ actions on the basis of their desires and beliefs, and it also has a “mirror system”, involved both in understanding others’ goals and intentions, and in empathizing with their emotions by means of a motor resonance mechanism. The importance of human sociality is reflected in the so-called “social brain hypothesis”. According to this theory, there are two reasons why primates have their large brains: the first function is to process information of ecological relevance, but above all large brains must to be able to cope the demands associated with living in large and complex social groups, a feature which distinguishes primates from most other animal species (Dunbar, 1992, 1995). Thus, an important shift is taking place in the so-called “social cognition” research, from a focus on the individual mind toward participatory aspects of social understanding.

The general term “social cognition” is used to describe cognition involving others, for example understanding others’ emotions, intentions, and actions, and acting towards and with them in social contexts (De Jaegher, Di Paolo, & Gallagher, 2010). As well as understanding others, social cognition involves understanding with others (De Jaegher & Di Paolo, 2007; Gallagher, 2009). Following embodied approaches, social cognition involves the know-how that allows us to sustain interactions, form relations, understand each other, and act together (Varela, Thompson, & Rosch, 1991; Clark, 1997).

A recent definition of social cognition is as follows: “Social cognition explains the mechanisms of social behavior using concepts and methods shared with related fields of cognitive psychology and cognitive science as well as new fields such as cognitive, social, and affective neuroscience.” (Winkielman & Schooler, 2008, p. 49).

The study of social cognition includes questions as the following: How do we explain our own and others’ behavior? What are the theories which underlie these explanations? How do we develop and maintain our self-concepts of the kind of people we are? What role do our self-concepts play in guiding our interpretations of the world and other people? How do we make judgements about the characteristics of ourselves and other people? How do we figure out what other people are thinking and feeling? What information do we use and how do we use it? What role do cognitive processes play in social interaction? How do our impressions of others guide our behavior in social interaction?

These questions are addressed through the investigation of topics such us how we understand other people’s minds (theory of mind), feelings (empathy), and actions (action observation and “mirror neuron systems”); moreover, studies on social cognition focused on topics concerning the self, the process of stereotyping and our capacity for emotion regulation. Same of these issues, relevant for the present work, will be discussed further below (see section 1.5).

Although the first articles and books referring to the “social brain” were published in the early 1990s (e.g., Cacioppo & Berntson, 1992; di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Baron-Cohen, 1995; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996; Brothers, 1997; Frith & Frith, 1999), social cognitive (neuro)science is characterized as a broaden movement and as a new interdisciplinary attempt, combining approaches from various disciplines including developmental, clinical, comparative, and social psychology, cognitive neurosciences and (neuro)economics, biology, evolutionary anthropology, and philosophy, only around the turn of the century (for a review, see Singer, 2012).

Social cognitive neuroscience is aimed to understand phenomena as results of interactions between three levels of analysis: the social level, related to the motivational and social factors that influence behavior and experience; the cognitive level, related to the information-processing mechanisms that cause social-level phenomena; and the neural level, related to the brain mechanisms that underlie cognitive-level processes. Whereas the traditional social and cognitive psychological researches make reference only to the first two levels of analysis, the social cognitive neuroscience approach implies conducting studies and consequently constructing theories that make reference to all three levels of analysis (Ochsner & Lieberman, 2001). Thus, the label social cognitive neuroscience indicates both the interdisciplinary nature of the field and its emphasis on integrating data derived from multiple levels of analysis.

It may be interesting trying to see in more detail how traditional cognitive (neuro)scientists and social psychologists worked and their mutual perspectives, to better understand the novelty and the importance of this new interdisciplinary field of research. Cognitive (neuro)science has historically been focused on the study of basic abilities with little interest for the personal and situational conditions that elicit and influence them, thus primarily considering the human brain in isolation and neglecting the social nature of humans. From this perspective, the understanding of real-world phenomena is a bottom-up process. Taking this approach, researchers have tried to investigate a variety both of human primary sensory functions such as vision, hearing, taste, and touch, and higher cognitive functions such as memory, problem solving, executive functioning, complex planning, and even consciousness (Gazzaniga, 2009). In contrast, social psychology has historically been interested in a broad range of complex and socially relevant phenomena that involve the self, how the self relates to others, and the impact of emotion and motivation on judgement, behavior, and experience. From this perspective, understanding social phenomena is a top-down process that begins with the real-world topic of interest. Following this approach, social psychologists have studied mechanisms and brain systems underlying classical social psychological phenomena, such as stereotyping, attitudes, self-knowledge, and interactions in groups (for a review, see Gilbert, Fiske, & Lindzey, 1998).

In the late 1970s and early 1980s, the adoption of the aforementioned information-processing metaphor offered a set of conceptual tools to explain the similarities and differences between different interconnected phenomena, and this transformation influenced social psychology. A decade later, when data about the brain began to be used to constrain theories about different cognitive processes underlying, for example, memory (e.g., Shacter, 1990), attention (e.g., Posner & Peterson, 1990), and vision (e.g., Kosslyn, 1991), cognitive psychology underwent an analogous change. In this way, the field of cognitive neuroscience was born and today the cognitive neuroscience approach is used to study most topics in cognitive psychology, putting together the top-down and bottom-up approaches that cannot be used independently since they are linked to each another.

As it will be explained more extensively in the next sections, a relevant point for cognitive neuroscience is the notion of close perception-action link, as suggested by ideomotor theories (Prinz, 1997), that has received much attention also due to converging neurophysiological evidence on the so-called mirror neurons (for a review, see Rizzolatti & Craighero, 2004). Moreover, the use of neuropsychological populations and functional neuroimaging techniques (e.g., functional magnetic resonance imaging, fMRI) has undergone an increase, because of their importance for directly connect social and emotional functions with neurocognitive systems, and their utility to test new hypotheses about the nature of social cognition (Adolphs, 1999; Cacioppo, Tassinary, & Berntson, 2000). The advantage of this new approach to psychology and to social behaviour is that, by specifying the underlying processes using terms taken from information theory and computer science, it is possible to bridge the gap between mental processes and brain function.

1.3 The perception-action link

As mentioned above, over the past decade, cognitive and neuroscientific researches have shown the existence of a mirror system in our mind and brain. In the next section, we will see that this system simulates the actions we observe (Jeannerod, 2003) by mapping an observed action onto a motor representation of the same action in the observer, thus activating specific cortical networks (Rizzolatti et al., 1996). Such a mirror mechanism implies that, at some level, action must be intrinsically linked to perception. Before seeing the mirror system in more detail, it can be useful to identify and understand the origins of such modern neurocognitive theories about action and perception.

Over the years, many psychologists have claimed that when we perceive another person's behavior we experience a sort of tendency to behave similarly. The origin of the modern motor theory of action perception can be dated to the early work of Lotze (1852). Following Lotze, James (1890) stated that merely thinking about a behavior increases the tendency to engage in that behavior; namely, the mere imagination of an action is sufficient to arouse the motor programs used for executing that action. Later, Greenwald (1970) claimed that also perception of external information can automatically induce action. This so-called "ideomotor principle" of action control highlights that actions are represented not only in terms of body movement but also in terms of the distal perceptual effects they aim to generate. A "common-coding" principle was postulated by researchers, for example, also to explain the rapid language acquisition in young children. In this regard, Lashley stated that "the processes of language comprehension and language production have too much in common to depend on wholly different mechanisms" (Lashley, 1951, p. 120). Later, the existence of a common or shared representational system for language comprehension and action codes was postulated by Prinz (1990). He hypothesized that the coding system both for perceiving behaviors in others and for performing those behaviors is the same, and it cannot be used at the same time to perceive and perform a behavior. In this way, action and perception are coded in a common representational medium, as postulated by the so-called "common coding theory" of action (Prinz, 1997). Following this theory, when a given movement is executed, an association is created between the motor pattern and the sensory effects and, in the reverse direction, the anticipation or perception of the sensory effects can induce a movement (Hommel, Müssler, Aschersleben, & Prinz, 2001).

1.4 Towards a unifying neural hypothesis of the basis of social cognition

As claimed before, social cognition is the study of how people interact with other individuals in social situations. A more relevant aspect of social interaction is the ability to understand what others are doing, their intention, and their feelings (Rizzolatti & Fabbri-Destro, 2008). As will be discussed in the present section, several findings of the last two decade showed that this capacity is mediated, in part, by a specific mechanism, the so-called mirror mechanism (Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Rizzolatti, Fadiga, Fogassi, & Gallese, 1999). The fundamental role of this mechanism is to transform sensory information of others' actions into a motor format, similar to that internally generated when observers imagine themselves doing that action or when they actually execute it. It is through this similarity between the motor format generated by others' observation and the format internally generated during motor and emotional behavior that observer are able to understand others' behavior, without any complex cognitive elaboration (Rizzolatti, Fogassi, & Gallese, 2001). Indeed, the mirror mechanisms allow us to directly understand the meaning of others' actions and emotions by internally replicating them ("simulation process") without any explicit reflective mediation or conceptual reasoning. Even if we are able to reason about others and to use this capacity to understand other people's minds at the conceptual, declarative level, the crucial process that allows us a direct experiential comprehension of the others' mind is a direct simulation of the observed events through the mirror mechanism (Gallese, Keysers, & Rizzolatti, 2004). In this sense, the discover of mirror neurons represents a milestone in the progress of social cognitive neuroscience.

What differentiates social interactions from our perception of the world is that not only we see others' actions and we perceive others' emotions, but we also perform similar actions and we experience similar emotions. In fact, there is something shared between our first- and third-person experience of these phenomena: both the observer and the observed have a similar brain–body system. For this reason, in the context of social cognition a fundamental aspect is the brain's capacity to directly link the first- and third-person experiences: this mechanism is defined "simulation" (e.g., Gallese & Goldman, 1998; Gallese et al., 2004).

The conventional conceptual approach has traditionally explained actions performed by others considering observed actions in a similar way to other visual stimuli, namely as an integration of all the separate elements that produces the neural input to a central conceptual system that interprets the visual representation (e.g., Fodor, 1982).

In recent years, a different theory has been formulated to explain how others' actions can be understood, basing on the discovery of a set of neurons called "mirror neurons". These neurons, originally found in the ventral premotor cortex (area F5) of the macaque monkey, become active both when the animal performs a specific goal-directed action (e.g. picking up a peanut), and when it observes the same specific action (e.g., grasping the peanut) being performed by someone else (di Pellegrino et al., 1992; Gallese et al, 1996; Rizzolatti et al., 1996; for a review, see Rizzolatti & Craighero 2004). The implication of this finding is that the observation of an action automatically activates parts of the same cortical neural network that is active during its execution (Rizzolatti et al., 1999).

Mirror neurons have not yet been definitively identified in humans, as it is only rarely possible to measure the activity in single neurons (but see Hutchison, Davis, Lozaro, Tasker, & Dostrovsky, 1999; Mukamel, Ekstrom, Kaplan, Iacoboni, & Fried, 2010). However, there are several findings for resonance behaviour in humans both at the behavioural and at the physiological level. Indeed, data from brain imaging, positron emission tomography (PET; e.g., Grafton, Arbib, Fadiga, & Rizzolatti, 1996), magneto-encephalography (MEG; e.g., Hari, Forss, Avikainen, Kirveskari, Salenius, & Rizzolatti, 1998), and transcranial magnetic stimulation (TMS; e.g., Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995) have shown that, also in humans, the observation of actions performed by others activates cortical motor representations. Namely, have been identified brain areas that become active both during the performance of the action and during the observation of the same action being performed by another person (Keysers & Gazzola, 2006; Rizzolatti & Fabbri-Destro, 2008). This means that when we see someone performing an action, there is not only the activation of various visual areas, but also a concurrent activation of part of the same motor circuits that are activated when we perform that action. In fact, part of our motor system becomes active “as if” we are executing the same observed action, even if we do not overtly reproduce that action (Gallese et al., 2004).

This mechanism, which explains the comprehension of action basing on the mirror neuron system, can be considered conceptually similar to the proposal advanced by phenomenologists and, in particular, by Merleau-Ponty. For example, with regard to what it means to understand an action, he claims that “the sense of gesture is not given, but understood, that is recaptured by an act of the spectator's part" (Merleau-Ponty, 1962, p. 185), a description that well explains the direct experiential understanding of the observed actions mediated by the mirror mechanism.

The idea of shared circuits, initially proposed for actions (Gallese & Goldman, 1998), actually appears much broader. In fact, the mirror system is present in different cortical areas and mediates different functions, according to its anatomical location (for other mirror mechanisms, see Rizzolatti & Craighero, 2004; Fabbri-Destro & Rizzolatti, 2008). The mechanism that I mentioned so far, the "shared-circuits for actions", is located in the parieto-frontal network (which includes the rostral part of the inferior parietal lobule, the caudal sector of the inferior frontal gyrus, and the adjacent part of the premotor cortex), and it underlies the understanding of the goal of the observed motor acts and the intention behind them (Rizzolatti et al., 2001). Similarly, shared networks for sensations have been identified in the primary and secondary somatosensory areas, involved both in experiencing touch on our own body and in viewing other human beings being touched (e.g., Keysers, Wicker, Gazzola, Anton, Fogassi, & Gallese, 2004; Blakemore, Bristow, Bird, Frith, & Ward, 2005). Finally, the mirror mechanism is also present in the anterior cingulate and insular cortices, and is involved in understanding of others' emotions. The extension of the idea of mirror system to the domain of emotions has led to empathy research (e.g., Preston & de Waal, 2002; Decety & Jackson, 2004; Decety & Lamm 2006; de Vignemont & Singer 2006), to which I will refer later (see section 1.5.4).

Common to all these cases (actions, sensations, and emotions) is that some brain areas are involved both in the first person experience (I do or I feel) and in the third person perspective (knowing what he/she does or he/she feels). This sharing is able to transform what we see another person do or feel into an inner representation of what we would do or feel in a similar situation ("simulation theory"; e.g., Gallese & Goldman, 1998; Gallese et al., 2004). According to this view, the activation of the cortical motor or viscero-motor centers is the crucial element for both first- and third-person comprehension of social behavior. When there is an activation of the downstream centers, the outcome is a specific action or emotional state. Instead, when only the cortical centers are active, without their peripheral effects, a simulation occurs of the observed actions or emotions.

There are several implications of having such shared circuits for actions. First of all, by transforming the sight of someone's actions into our motor representation of these actions, we can achieve a very simple and powerful understanding of others' actions, and this provides us an intuitive grasp (insight) of others' inner life (Gallese et al., 1996; Gallese et al., 2004; Keysers & Gazzola, 2006). Second, mirroring the actions of others might help to understand what another person is doing (Rizzolatti et al., 2001) or to predict what he/she is most probably going to do next (e.g. Blakemore & Frith, 2005). Third, this mechanism might underlie more sophisticated mental abilities, such as understanding the others' intentions (e.g. Iacoboni, Molnar-Szakacs, Gallese, Buccino, Mazziotta, & Rizzolatti, 2005). Finally, activating motor programs similar to the ones we have observed or heard might be useful in the imitation of others' actions (Iacoboni, Woods, Brass, Bekkering, Mazziotta, & Rizzolatti, 1999; Buccino, Vogt, Ritzl, Fink, Zilles, Freund, & Rizzolatti, 2004b).

1.5 Relevant topics in social cognition

As we have just seen, our brains have developed a basic functional mechanism, a mirror or shared-circuit mechanism, which could provide the first unifying perspective of the neural basis of social cognition (e.g., Gallese et al., 2004; Keysers & Gazzola, 2006; Singer, 2012). However, this mechanism tend often to be seen as a panacea to explain any issue of social cognition. It is important to note that while it plays several very important functions, such as those listed at the end of the previous section, it cannot explain everything (Keysers & Gazzola, 2006). In fact, while it could be excessive and erroneous to use the mirror mechanisms to explain every aspect of social cognition, ranging from imitation to language development and theory of mind, (e.g. Jacob & Jeannerod, 2005), mirror systems are relevant to some crucial processes in social interaction. It will remain for future research to outline the limits of what shared circuits can really explain.

In the next subsections we will see some relevant issues of social cognition (for a review, see Singer, 2012) to which I already previously mentioned. Some of them will be taken up and more detailed in the next chapters (see Chapter 2 for motor resonance and Chapter 4 for joint action).

1.5.1 Imitating action

The mirror effects that emerges when we observe motor actions can occur without awareness and thus involuntary. For example, observing someone performing an action different from our own, for example observing vertical movements of a human actor or of a robot while we are executing horizontal movements, makes our actions more variable and less accurate (Kilner, Paulignan, & Blackemore, 2003). Moreover, the effect seems to be specific to observation of human movement, since it did not occur when the movements were performed by a robot arm. The mirroring of others' actions seems to depend also on whether or not people believe that the movement reflects human motion or not, indicating that this tendency to imitate is at its strongest during social interaction (Stanley, Gowen, & Miall, 2007). In addiction, it has been shown that the observation of a movement leads to a stronger neural activation when the person performing actions is in visual contact with us (Kilner, Marchant, & Frith, 2006).

This mirror effect due to a neural activity elicited by action observation, which is stronger during social interaction with an agent similar to ourselves, can also become overt imitation. In fact, when two people interact they tend to non-consciously mimic the postures, mannerisms, facial expressions, and other behaviors of other partner, so that their behavior passively and unintentionally change and match the others' behavior. This is known as the "chameleon effect" (Chartrand & Bargh, 1999). The authors suggest that the involved mechanism is the perception-behavior link; namely, the simple perception of an action triggers corresponding action representations in the observer and thus it automatically increases the likelihood of performing oneself the same behavior (for a review, see Van Baaren, Janssen, Chartrand, & Dijksterhuis, 2009). Furthermore, the experience of mimicry causes an increase in prosocial behaviour (Van Baaren, Holland, Kawakami, & Van Knippenberg, 2004): the interaction are more easy and the partners like each other better when the mimicry occurs. Moreover, persons with high ratings on empathy scales show a greater degree of mimicry than others. However, these effects emerge only when people are unaware of such mimic behavior (Lakin & Chartrand, 2003).

1.5.2 Joint action

Considering the chameleon effect, it can be said that interacting people create joint actions in which simple movements are imitated. However, this mirroring can also emerge at more abstract levels about goals, influencing the speed with which decisions are made. For example, Sebanz, Knoblich, and Prinz (2003) required subjects to perform together a choice reaction time task concerning a spatial compatibility effect. Even if this issue will be more detailed later in Chapter 4 and will be the subject of two experimental studies that I have conducted (see Chapters 5 and 6), now I can briefly anticipate that, when acting together, each subject automatically represents the task requirements and goals both own and of the other subject. This result suggests that knowing about the potential actions of a partner increases the relevance of stimuli referring both to the self and to the other, and also increases the need to monitor one's actions (for a review, see

Knoblich, Butterfill, & Sebanz, 2011). In this example, subjects performed the respective task at the same time, but no cooperation was required to correctly perform their tasks. Instead, when cooperation becomes necessary in order to correctly execute a joint action, shared representations of task features and goals are crucial to attain good performance and results. Some authors studied this sharing in experiments on discourse and have defined it also as common knowledge or alignment that emerges automatically and without awareness (Clark, 1996; Pickering & Garrod, 2004).

1.5.3 Motor resonance

This topic, to which I have already referred in the previous sessions, will be more detailed in Chapter 2 and will be the subject of one experimental studies that I have conducted (see Chapter 3).

As regards the link between perception and action, generally the functional analysis proceeds from action perception to action production and can be classified under the notion of “motor resonance”, a notion already mentioned above (for a review, see Rizzolatti & Craighero, 2004). However, this view is incomplete, since there are at least two individuals involved in a social interaction who alternately assume the role of perceiver/observer and actor. This means that it is also essential to consider the possible role of mirror mechanisms from the perspective of the actor and, according to this view, it is also necessary to proceed from action production to action perception (Schütz & Prinz, 2007). Indeed, action production can influence action perception so that observers are selectively sensitive to some events in the environment. The motor or action knowledge can influence action perception and the perceptual system, so that perceiver might be selectively sensitive to those actions that are related to his/her own actions. Strong evidence for the claim that perceptual system is tuned to one’s own motor skills comes from the studies that investigated motor experts, for example from the works on dancers of Calvo-Merino and collaborators (Calvo-Merino, Glaser, Grèzes, Passingham, & Haggard, 2005; Calvo-Merino, Grèzes, Glaser, Passingham, & Haggard, 2006). As I will explain in more detail in the next chapter, these studied showed that the motor system was more strongly engaged during action observation when participants already had a specific motor representation of the action they observed. This means that our mirror neuron mechanism seems to be activated with differing intensity on the basis of the similarity between the actions we observe and the actions that are part of our motor competence.

The emergence of motor resonance to action also has an important social function: it might render an individual selectively tuned to similar actions of conspecifics, so that we can only perceive and understand in others what we can do ourselves. In this way, this mechanism becomes crucial for empathy.

1.5.4 Emotional contagion and empathy

As already mentioned, the initial idea that perception–action link enables us to understand other people’s motor action has been extended, so to include not only the ability to share motor actions but also the ability to share feelings and sensations (Preston & de Waal, 2002; Gallese, 2003; Decety & Jackson, 2004; Decety & Lamm, 2006; de Vignemont & Singer, 2006). Recent empathy studies have indeed highlighted the presence of such shared neural networks in the domain of emotions.

Early studies focused on emotional contagion caused by the perception of emotional expressions in faces. For example, they demonstrate that the sight of the facial expression of disgust activates the same brain areas involved during the direct experience of a disgusting smell (Wicker, Keysers, Plailly, Royet, Gallese, & Rizzolatti, 2003). Similarly, the sight of a fearful face activates the same brain areas involved during the direct exposure to a fearful object (Morris, Frith, Perrett, Rowland, & Young, 1996).

Subsequent studies demonstrated that such shared networks are not only activated when we are faced with emotional stimuli. In fact, humans possess also the ability to empathize with others when know that someone is suffering even in the absence of any explicit emotional stimulation. Here I will briefly refer to this topic as it will be resumed in Chapter 3. For example, in a seminal study Singer and colleagues (Singer, Seymour, O'Doherty, Kaube, Dolan, & Frith, 2004b) measured empathic brain activations elicited when participant received pain or when participant knew that her partner suffered pain. More specifically, authors recruited couples and measured empathy in vivo by registering brain activity with fMRI in the female partner while painful stimulation was applied either to her own hand, thus measuring pain-related brain activation of the felt pain, or to her partner's right hand, thus measuring pain-related brain activation of the empathy for pain. The results suggest that part of the so-called "pain matrix", prevalently the bilateral anterior insula (AI) and the anterior cingulate cortex, was activated both when subjects experienced pain themselves and when they saw a signal indicating that the partner had experienced pain. Activation in this network was also registered when subjects watched videos showing body parts in potentially painful situations (Jackson, Brunet, Meltzoff, & Decety, 2006), painful facial expressions (Lamm, Batson, & Decety, 2007), or hands being pricked by needles (Morrison, Lloyd, di Pellegrino, & Roberts, 2004; Morrison, Peelen, & Downing, 2007). Further studies suggest that the magnitude of these empathic brain responses can be modulated by different factors, such as the perceived fairness of the other (Singer, Kiebel, Winston, Dolan, & Frith, 2004a; Singer, Seymour O'Doherty, Stephan, Dolan, & Frith, 2006) and the intensity of the inflicted pain (Avenanti, Minio-Paluello, Bufalari, & Aglioti, 2006; for a review, see de Vignemont & Singer, 2006). As with the observation of actions, observation of other people's emotions often becomes overt mimicry.

So far, social neuroscientists have mostly investigated phenomena such as emotional contagion and empathy and, summarizing, the former indicates a reaction in which one shares an emotion with another person without realizing that the other person's emotion was the trigger; instead, empathy requires the awareness that our affective state was due to another person's affective state.

1.5.5 Theory of mind or mentalizing

As well as actual behaviour or motivational state of the other, also more abstract beliefs about who we are interacting with play a relevant role in our life and influence social interactions. In fact, when we interact with other persons, we assume that they have minds like our own and so we try to anticipate their behaviour considering the contents of their minds, namely their beliefs and desires. This is know as having a "theory of mind" or "mentalizing" (Premack & Woodruff, 1978; Frith 1989; Baron-Cohen, Tager-Flusberg, & Cohen, 2000), expressions used to indicate the general ability of an individual to attribute mental states such as intentions, desires or beliefs to oneself and others, and the ability to understand that others have intentions, desires, and beliefs that are different from one's own (Singer, 2012).

This ability has been widely investigated using different tasks including reading stories (Fletcher, Happé, Frith, Baker, Dolan, Frackowiak, & Frith, 1995; Saxe & Kanwisher, 2003), looking at cartoons (Brunet, Sarfati, Hardy-Bayle, & Decety, 2000; Gallagher, Happé, Brunswick, Fletcher, Frith, & Frith, 2000), or watching simple animations (Castelli, Happé, Frith, & Frith, 2000). Moreover, such ability has been extensively studied in both normal and abnormal development, for example highlighting that difficulty in understanding other minds is a core cognitive feature of autism spectrum conditions (e.g., Frith, 1989; Baron-Cohen, Tager-Flusberg, & Cohen, 1993). I will not go into details of these researches as beyond the scope of the thesis.

Interestingly, several studies have revealed the existence of the so-called "theory of mind or mentalizing network" that includes the medial prefrontal cortex (mPFC), the posterior superior temporal sulcus (STS) and the temporal poles (TP) (for reviews, see Frith & Frith, 1999, 2003; Gallagher & Frith, 2003; Amodio & Frith, 2006).

1.6 Overview and aim of the project

In conclusion, trying to briefly summarize what has been discussed so far, significant progress has been achieved in the last years in cognitive neuroscience and a significant change is going on the so-called "social cognition" research field, from a focus on the individual mind toward embodied and participative aspects of social comprehension. I have explored the origin and the recent development of the social cognitive (neuro)science, as a new interdisciplinary attempt which combines approaches from various disciplines, such as developmental, clinical, comparative and social psychology, cognitive neurosciences and (neuro)economics, biology, evolutionary anthropology, and philosophy (for a review, see Singer, 2012). The name social cognitive neuroscience indicates not only this interdisciplinary nature of the field, but also the importance attributed to the integration of data from multiple levels of analysis, ranging from the experience and behavior of individuals in relevant contexts (the social level) to the information-processing mechanisms that cause these phenomena (the cognitive level) to the brain systems that underlay these processes (the neural level) (Ochsner & Lieberman, 2001).

A crucial point for social cognitive (neuro)science is the notion of close perception-action link, as suggested by ideomotor theories (Prinz, 1997), that has received a growing attention due to converging neurophysiological evidence on the so-called mirror or shared-circuit mechanism (for a review, see Rizzolatti & Craighero, 2004), which could provide the first unifying perspective of the neural basis of social cognition (e.g., Gallese et al., 2004). Evidence that the same brain areas are involved both in the first person experience (I do or I feel) and in the third person perspective (knowing what he/she does or he/she feels) demonstrates that this sharing transforms what we see other people do or feel into an inner representation of what we would do or feel in a similar situation (simulation theory) (Keysers & Gazzola, 2006). Such shared or mirror system is crucial for some processes in social interaction.

Among the different topics addressed by the social cognitive (neuro)science, the aim of the present project is investigated motor resonance and joint action. Specifically, a series of targeted social cognitive experiments are been designed to elucidate the human mechanisms of motor resonance and joint action. To this aim, I decided to use two well-known and established effects of cognitive psychology: “Affordance” and “Simon”. Here is a summary of how I intend to proceed in this dissertation, useful to better explain the aim of my project.

In the first part of the thesis the notion of “Affordance” will be introduced beginning with the seminal definition and theorization of Gibson (1979), and his ecological perspective, up to the latest developments and to the concept of “Micro-affordance” postuled by Ellis and Tucker (2000). By means of an overview of various empirical findings and of an original research (Anelli, Nicoletti, & Borghi, 2010; Anelli, Nicoletti, & Borghi, in preparation b), I will explain how it can be possible to use the affordance effect to investigate the issue of motor resonance. In fact, the first experimental research presented in the thesis (Study 1; Anelli, Nicoletti, Kalkan, Sahin, & Borghi, in press b; Anelli, Borghi, & Nicoletti, under review) was aimed both to verify how responses to objects and sensitivity to fine object characteristics develop, examining the influence of a micro-affordance that can be defined dangerousness, and to investigate how motor resonance develops. The experiments conducted both with children and adults have allowed to study active responses to dangerous stimuli and the effects of social variables, such as gender and age of participants, thus investigating fine-grained resonant mechanisms.

The second part of this thesis concerns the other chosen paradigm. The "Simon" effect will be presented both at a theoretical and empirical level, starting from the first experimental evidence (Simon & Rudell, 1967) to the most recent researches on the so-called "social or joint Simon effect" (Sebanz et al., 2003). The overview will be useful to understand how, through the social or joint Simon effect, it is possible to examine the issue of joint action. In fact, the purpose of the other two studies presented in the thesis was to investigate whether shared representations, as indexed by the presence of the joint Simon effect, are influenced by perceived group membership. More specifically, the Study 2 (Iani, Anelli, Nicoletti, Arcuri, & Rubichi, 2011; Anelli, Nicoletti, Arcuri, Rubichi, & Iani, in press a) has explored both the role of minimal ingroup–outgroup distinctions and of type of interdependence between participants on the modulation of shared representations, also taking into account theories and data of social psychology (Rabbie & Horwitz, 1969; Tajfel, Billig, Bundy, & Flament, 1971). Along the same research line, the Study 3 (Anelli, Iani, Nicoletti, & Rubichi, in preparation a) was aimed to further clarify the role of the type of interdependence between participants on the shared representations emergence, combining the use of joint Simon and "joint transfer of learning" (Milanese, Iani, & Rubichi, 2010) paradigms, and even considering related evidence from social psychology (Sherif , Harvey, White, Hood, & Sherif, 1961; Sassenberg, Moskowitz, Jacoby, & Hansen, 2007).

Finally, a general discussion of the three studies will highlight the original contribution of the presented results and their importance within the Social Cognition research.

PART 1

CHAPTER II

AFFORDANCE EFFECT

As anticipated in the previous chapter, the first part of the thesis concerns the "Affordance" theme. Thus, in the present chapter I discuss this issue both at a theoretical and empirical level. First, I will focus on the origin of the Gibson's notion of affordance and on the conditions that allow affordances to emerge. Second, a paragraph will be dedicated to post-Gibson theorizations, giving particular attention to the notion of "Micro-affordance" developed by Ellis and Tucker, underlining both the similarities and the differences from the Gibsonian notion, and presenting some important empirical findings obtained with different techniques (e.g., behavioral, neurophysiological, and neuroimaging). Then, I will present an original research to illustrate how it is possible to investigate the notion of affordance through experiments using a methodology of cognitive psychology; in particular, the work investigates the role of object consistence in adults by measuring the participants' response times in different categorization tasks. Finally, a section will be dedicated to trying to understand how it is possible, by using the "affordance effect", to investigate a relevant topic of social cognition, the motor resonance, which will be the subject of the Study 1, presented in the next chapter.

2.1 Definition and Gibsonian notion of affordance

Over the past decade, a growing number of cognitive and neuroimaging studies have focused on affordances. In the 1979 for the first time Gibson proposed a theory of affordances, defining them as properties in the environment that are relevant for an organism’s goals. In other words, affordances are what the environment offers to acting organisms (for example, an apple offers us the possibility to be grasped and eaten). It is important to underline that an affordance is not an object, but rather it is the outcome of a process. It can be argued that the notion of affordance represents the result of an approach to cognition that avoids the use of mental representations and strongly emphasizes the relation between knowledge and action (Good, 2007). Such attempt is the “Ecological approach” to perception, developed by James Gibson in a period of about thirty years and culminated in the book “The Ecological Approach to Visual Perception” (Gibson, 1979). As we shall see, the ecological approach underlines the mutuality of the perceiving organism and environment, and the reciprocity of perception and action.

Before discussing in more detail the notion of affordance and to better understand its novelty, it could be useful to briefly present the origin of the Gibson’s ecological approach, highlighting its main differences with respect to the conventional cognitivist approach (Zhang & Patel, 2006). First of all, I can consider the starting point. For the conventional theory of perception, the starting point for perception is the retinal image, it is the stimulation of light on the retina that provides information for visual perception. According to Gibson, the starting point is the ambient optic array, it is the structure in the light that provides direct information to the observer about the media, surfaces, substances, and events. Second, the level of description. According to Gibson, the right level of describing perception is ecology, not physics or geometry, as claimed by the conventional theory of perception. From his point of view, perception can be intended as the direct pickup of invariant properties in the optic array. Third point, the static vs. active perception. For the conventional theory, perception is a passive detection of the retinal image. According to Gibson, however, perception is an act: perception and action are seen as strongly interconnected, as stimulation per se does not lead to perception. Fourth, mediated vs. direct perception. According to the conventional theory, perception is a computational process, mediated by inferences which are the elaborations of mental representations. What one perceives depends not only on the stimulation of light, but also on the mental processes used in processing that information. According to Gibson, however, perception is not mediated by memory, inference, nor by any other psychological process and mental content in which internal representations are organized. This means that humans can directly perceive objects in the world on the basis of the pickup of invariants in the optic array, as previously stated, and such invariants specify all objects and events in the environment. Last point, the complementarity of the organism and the environment. For the conventional theory, perception is the processing of the retinal image formed by the stimuli in the environment and thus is a one-way perception. According to Gibson, however, perception of the environment is also the perception of the self. The environment and the organism are mutually complementary and linked. The environment implies the organism and vice-versa.

Recovering more in detail what has emerged so far, Gibson defined affordances as properties in the environment providing the observer with practical opportunities which he/she is able to perceive and use (Costantini & Sinigaglia, 2012). The relations between the physical structures of the environment and the physique of the organism are the elements that specify the affordances (e.g., a chair affords sitting for people). To explain the Gibson's original affordances, to these elements must be added two fundamental properties: the complementarity of the environment and the organism, and the direct, effortless pickup of affordances (Zhang & Patel, 2006). Indeed, "the affordance of the environment are what it offers the animal, what it provides or furnishes, either for good or ill... I mean by it something that refers to both the environment and the animal in a way that no existing term does. It implies the complementarity of the animal and the environment" (Gibson, 1979, p. 127). As affordances are relative to animals, they can only be measured in ecology, but not in physics, as anticipated above.

Affordances can be registered directly by our perceptual system, are invariant and holistic: when we look at an object, we perceive its affordances, not its dimensions and properties. Affordances should not be construed as just objective or subjective properties, nor should they be considered as purely physical or psychical in nature, since they "cuts across the dichotomy of subjective and objective [being] equally a fact of the environment and a fact of behaviour. It is both physical and psychical, yet neither. An affordance points both ways, to the environment and the observer" (Gibson, 1979, p. 129). Hence, affordances only make sense from a system point of view.

This last point recalls a concept particularly relevant for an embodied perspective: the conditions allowing affordances to emerge pertain to both perception and action. They are properties neither of the object/environment nor of the acting organisms, but they are intrinsically relational properties. For example, a door handle affords opening only for humans, not for other living beings (animals or plants). Namely, affordances are specific for a particular organism and related to its own body structure, and bodily characteristics.

As previously noted, affordances are based on object properties that are registered directly by our perceptual system, without the mediation of object recognition and of semantic knowledge: "You do not have to classify and label things in order to perceive what they afford" (Gibson, 1979, p. 134). Namely, the pattern of stimulation induced by the object in the perceiver specifies the behavioral possibilities afforded by objects.

2.2 From Gibson's view to micro-affordance

As we have seen, Gibson's ecological psychology was developed primarily for visual perception. Gibson considered the implications of his ecological approach and theory of affordances for other domains of psychology and for philosophy. However he could not extend his theory to the mainstream cognitive psychology, because of his hypothesis of direct perception and not mediated by internal representations nor by any other psychological process.

Neisser (1994) and Shepard (1984) tried to reconcile Gibson’s ecological view, that focuses on the importance of the information in the environment, and cognitive psychology, that focuses on the role of internal representations. For example, studying the ecological constraints of internal representations, Shepard (1984) claimed that not only perceiving, but also imagining, thinking, and dreaming are driven by internalizations of long-lasting external constraints. According to Shepard, instead of picking up the invariants that are present in the sensory arrays, as a result of both biological evolution and perceptual and cognitive learning, an organism selectively resonates to the invariants that are significant for it.

Gibson’s ecological psychology and his theory of affordances have been elaborated in the areas of human factors and applied cognitive science. To give some examples, in the book “The Psychology of Everyday Things”, Norman (1988) explored the roles of affordances, forcing functions, and natural mappings in the design of cognitive artifacts; Kirlik and Bisantz (1999) built a process model of skilled human-environment interaction; Gaver (1991) also applied and extended this theory in the design of computer displays.

Several attempts have been made to clarify what type of properties affordances are. Some researchers have pointed out that affordances are dispositional properties of the environment that must be integrated with some dispositional properties of individuals (e.g., Shaw, Turvey, & Mace, 1982; Turvey, 1992). Instead others expressed a different perspective. Among these we can mentioned Chemero who claimed that affordances are relations between the features of a situation and the abilities of an individual, and thus they are not properties of the environment related to the observer (2001, 2003, 2009). The importance to differentiate properties and features is that to perceive a property of an object one must identify the object and know that the object has that property (Costantini & Sinigaglia, 2012). Conversely, to perceive an affordance, "there is no need to know anything about any particular entity" (Chemero, 2009, p. 140), since the ability to perceive is sufficient. Similarly, individual abilities cannot be defined as dispositional properties, since "there is something inherently normative about ability: individuals with abilities are supposed to behave in a particular way, and they may fail to do so. Dispositions, on the other hand, never fail; they simply are or not in the appropriate circumstances to become manifest" (Chemero, 2003, p. 189). Finally, abilities are interconnected and hierarchically organized, so that all other abilities are based on more basic abilities, namely on primary motor abilities.

Several researchers have postulated that to interact appropriately with an object, it is necessary to integrate the affordances it provides with our previous experience of interaction and use of the same or similar objects (Borghi, 2005). Such experience does not need to be direct, but it can also derive from observation. For example, Mareschal and Johnson (2003) found that four-months-olds infants are able to acquire information related to the affordances of an object through merely observation of others rather than through direct experience. Independently of whether this experience is direct or acquired by imitation, what we see might reactivate previous visuomotor experiences with objects, thus influencing the way we respond to them. In this regard, a good definition of affordance is provided by Humphreys, who claimed that affordances might be based on stored conceptual knowledge, but not necessarily: "What I mean by the term is some direct link between the perceived visual properties of an object and an action that may be performed with it. This link between the perceived properties of objects and actions may be, but does not need to, be based on a stored representation of the particular object" (Humphreys, 2001, p. 408).

Recently, among the studies focusing on the role of affordance in the control of the action, Fajen (2007, 2008) proposed an innovative approach, the so called “affordance-based control”, starting from the “information-based control” and the “model-based control” approaches. He argued that key aspects of the information-based control and the theory of affordances can be merged and create a new theoretical approach. Affordance-based control postulated that the primary function of perception is to allow individuals to see the world in terms of what they can and cannot do. Successful performance depends on the perception of possibilities for action (i.e., affordances) that are perceived directly from information in optic flow. This approach highlights the close relation between information in optic flow and movement that is characteristic of visually guided action. Moreover, it may also explain how individuals consider the dynamic properties of their body and the environment: the perception of affordances must be recalibrated following a change in action capabilities and a scaling of task-specific information.

Recent views of affordances indicated affordances as brain representations of action possibilities, namely as the result of previously stored perception-action experiences (Ellis & Tucker, 2000). Affordances can be divided into two main categories, on the basis of the corresponding motor abilities. The first is labelled “walking-like” or “macro-affordances” and includes the affordances where the situation requires motor abilities in locomotion or navigation (e.g. walking, climbing, jumping, going up, going down, etc.). The second category is named “grasping-like” or “micro-affordances”, that is, the affordance relations where the situation requires interactions towards an object (e.g. hand- or mouth-grasping, manipulating, tearing, pulling, pressing, biting, kicking etc.).

In the following I will focus on the second category of affordances, more relevant to the present work. Thus, giving a look at micro-affordance, it is interesting to note that, to underline both the similarities and the differences from Gibsonian affordances, Ellis and Tucker (2000) proposed the name of “micro-affordances” to refer to the potential elements of an action. Micro-affordances can be defined as “brain assemblies” that represent objects, namely they are the result in the brain of the connection between visual responses and action-related responses that have developed during the process of adapting to the environment. Similarly to Gibsonian affordances, micro-affordances are elicited automatically, independently from the goal of the actor, thus they refer to simple actions and not to complex actions, in which plays a role the goal of the actor (for example, eating or drinking). Instead, micro-affordances facilitate simple and specific kinds of interaction with objects that also involved the activation of conceptual knowledge (Borghi, 2005). In fact, micro-affordances differ from Gibsonian notion, since they are much more specific and are a consequence of object-based attention (Vainio, Ellis, & Tucker, 2007). They do not elicit grasping, but a specific component of grasping which is more appropriate to a particular object.

2.2.1 Empirical evidence

The relational nature of micro-affordances was confirmed by several empirical findings obtained with different techniques (e.g., behavioral, neurophysiological, and neuroimaging techniques). Behavioral studies demonstrated that the mere observation of something graspable retrieves the appropriate set of hand-action possibilities, even when there is not a real interaction or intention to act (Craighero, Fadiga, Rizzolatti, & Umiltà, 1999). More specifically, it has been shown that the execution of left-right hand motor acts are influenced by task-irrelevant object information (e.g. the left-right orientation of the handle of a mug), so that a facilitation effect emerges when the orientation of the affording part of the object (e.g. handle) and the responding hand are spatially correspondent (Ellis & Tucker, 2000; Tucker & Ellis, 1998, 2001, 2004). Phillips and Ward (2002) reported an analogous compatibility effect between object orientation and motor act execution, presenting participants with a visual manipulable object-prime oriented towards or away from participants, or in a neutral position, followed by a target requiring a response with the left or right hand, or a foot press. The results showed that lateralized responses were facilitated by object handles oriented in a corresponding way. On the whole, several studies with compatibility paradigms have demonstrated that the vision of objects activates a motor simulation and might even evoke overt reaching and grasping movements (e.g., Tucker & Ellis, 1998, 2001; Bub, Masson, & Bukach, 2003; Edwards, Humphreys, & Castiello, 2003; Borghi, 2004; Tipper, Paul, & Hayes, 2006; Borghi, Bonfiglioli, Lugli, Ricciardelli, Rubichi, & Nicoletti, 2007; Bub, Masson, & Cree, 2008; Fischer, Prinz, & Lotz, 2008; Vainio, Symes, Ellis, Tucker, & Ottoboni, 2008).

Neurophysiological and neuroimaging studies showed that, both in monkeys and in humans, specific parieto-frontal circuits encode the observed situation features in terms of one or more action potentialities. The perception of affordance implies that the same neurons are activated both to encode the motor acts they control (e.g. hand-grasping) and to respond to the situated visual features requiring those motor acts. In monkeys, single cell recordings from the ventral premotor cortex (area F5) have shown the existence of a special class of visuo-motor neurons, the so-called “canonical neurons”, that seems to constitute the neural basis for affordances. These neurons discharge in the presence of graspable object, even when the monkey was just fixating it and thus no overt response is required (Rizzolatti, Camarda, Fogassi, Gentilucci, Luppino, & Matelli, 1988; Jeannerod, Arbib, Rizzolatti, & Sakata, 1995; Murata, Fadiga, Fogassi, Gallese, Raos, & Rizzolatti, 1997; Raos, Umiltà, Murata, Fogassi, & Gallese, 2006; Umiltà, Brochier, Spinks, & Lemon, 2007). A congruence effect has been observed between the type of grip coded by a given neuron and the size and shape effective in activating corresponding visual response (Sakata, Taira, Murata, & Mine, 1995). Indeed, most neurons are selectively activated by specific kinds of grips (e.g., precision vs. power or full hand grips), suggesting that they probably represent objects in terms of potential action patterns.

As for humans, similar results have been registered. For example, an early PET study (Grafton, Fadiga, Arbib, & Rizzolatti, 1997) showed the automatic activation of the left premotor cortex during the observation of manipulable objects, even in the absence of motor output. Further fMRI studies demonstrated the activation of the left premotor cortex and the inferior parietal lobule when graspable objects were observed (Chao & Martin, 2000), and that this fronto-parietal circuit was activated during the execution of a given hand grip depending on the specific hand grip afforded by the object features (Grèzes, Tucker, Armony, Ellis, & Passingham, 2003). Other brain activation studies showed that the response of the left ventral premotor cortex was stronger for manipulable than for non-manipulable objects (Gerlach, Law, & Paulson, 2002; Kellenbach, Brett, & Patterson, 2003). Several fMRI and PET studies have shown that the brain is differently activated by tools compared to other objects which do not evoke actions, such as animals and faces (e.g., Martin, Wiggs, Ungerleiden, & Haxby, 1996; Chao & Martin, 2000; Grèzes & Decety, 2002; Johnson-Frey, 2003; Boronat, Buxmaun, Coslett, Tang, Saffran, Kimberg, & Detre, 2005; Creem-Regehr & Lee, 2005; for a review, see Martin, 2007), and that left premotor cortex was also activated during the recalling of actions associated with tools (Grafton et al., 1997). Along this line, more recently Buccino and colleagues (Buccino, Sato, Cattaneo, Roda, & Riggio, 2009) investigated with a TMS paradigm the excitability of the primary motor cortex during the observation of manipulable objects (e.g., a mug). Notice that the handle of the objects could be broken, thus reducing the corresponding affordance. Results showed that MEPs were larger when the handle of the object was complete, thus suggesting that the cortical motor system plays a crucial role not only in the programming and online control of movements, but also in the processing of the features of the objects that allow us to perceive them in terms of affordances, and thus as effectively graspable or not.

Both behavioural and brain imaging studies, of which I have mentioned only few examples, leave open different questions. An interesting point concerns the existence of different kinds of affordance. As we have seen, behavioral studies showed the emergence of compatibility effects, for example between handle orientation of the object and key to press (Tucker & Ellis, 1998; Phillips & Ward, 2002), and between object size and the kind of grip used to respond (Ellis & Tucker, 2000). Borghi and Riggio (2009) proposed that might be possible to distinguish different kinds of affordances: stable affordances, such as shape and size, which depend on information stored in memory, and temporary affordances, such as orientation, which refer to object properties that can vary depending on the context. Such affordances might refer to different cognitive and neural systems. Referring to the analysis of visual behavior of Ungerleider and Mishkin (1982), Milner and Goodale (1995, 2008) proposed the existence of two mechanisms responsible for visual processing: the ventral and the dorsal streams. More specifically, the ventral stream runs from visual cortex (VC) to inferotemporal cortex (ITC) and is responsible for the objects recognition (“what” pathway). Instead, the dorsal neural stream runs from VC to parietal cortex (PC) and processes object-directed actions (“where” pathway). Milner and Goodale (1995) also postulated the existence of an off-line mode that involves the ventral stream and an on-line mode that depends on the dorsal stream. Affordances of objects are thought to be encoded by the dorsal stream, however, if there are different kinds of affordances, they could sub-served by different neural pathways (Young, 2006). Temporary affordances, useful for reaching and grasping actions, probably involve primarily the dorsal stream, instead stable affordances may involve the ventral stream. In accord to this view, recent studies suggested a less rigid distinction and proposed that the dorsal route can be distinguished into a pure dorsal-dorsal route and a ventral-dorsal route

(Gentilucci, 2003; Rizzolatti & Matelli, 2003). This three-way distinction might allow to discriminate between stable and variable affordances.

Taken together, both behavioural and brain imaging studies have shown that perceiving affordances activates in observers specific motor programs, and it can be argue that micro-affordances are relations between features of situations and individual abilities.

2.3 An affordance effect case-sample: the object consistence

As anticipated, now I would present an original research (Anelli et al., 2010) as example of how it is possible to empirically investigate the notion of affordance by means of the methodology of cognitive psychology.

Literature on categorization has focused on the importance of a variety of perceptual properties. Extrinsic properties, i.e. invariant object features, such as object shape (e.g., Panis, Vangeneugden, Op de Beeck, & Wagemans, 2008; Panis, Vangeneugden, & Wagemans, 2008) and object size (e.g., Tucker & Ellis, 2001), have been extensively investigated; in addition, intrinsic properties that cannot be visually detected, such as weight (e.g., Brouwer, Georgiou, Glover, & Castiello, 2006; Scorolli, Borghi, & Glenberg, 2009), have also been studied. However, an important property related to both object perception and manipulation has not been extensively studied. To our knowledge there are no studies on adults showing how physical object malleability (from now on consistence) might influence the way humans categorize and represent category members. This strikes us as surprising because consistence is a relevant and peculiar object property, since it can be estimated simply by seeing objects, but, in order to be determined with a certain degree of reliability, it also requires direct object manipulation. In addition, information on how to manipulate objects, and, in particular, on whether objects are hard or soft, becomes part of our long term semantic knowledge.

This study fills a gap in research on affordances as it clearly demonstrates the importance of object consistence in different categorization tasks performed by adults. To our knowledge the role of consistence has mainly been investigated focusing on infants' and children's categorical organization.

Even if the majority of studies on categorization have focused on shape, size, and texture, there are some researches which have investigated the role played by consistence and object malleability in categorization. For example, Gibson and Walker (1984) observed that 1-month-olds infants were able to extract information about the softness or rigidity of an object merely through exploration by the mouth. Rochat (1987) presented neonates and 2- and 3-month-olds infants with objects which were identical in shape, texture, and dimension but which varied in consistence. He demonstrated that infants respond haptically in a different way to hard and soft objects, and this difference is modulated by the response modality, oral or manual. This result indicates that infants' behaviour is not under the control of reflexive mechanisms but is rather sensitive to affordances emerging from objects. Overall, results on neonates and infants reveal that the sensitivity to object consistence develops quite early.

Relevant to our aims are studies investigating the so-called "shape bias" in categorization. Since the seminal work of Landau, Smith and Jones (1988), a variety of experiments have provided evidence in favour of the shape bias, that is the tendency to extend new labels to objects similar in shape rather than in size, colour, and texture. For example, children classify objects endowed with animacy cues, such as objects with eyes, by both shape and texture, whereas they classify eyeless objects only on the basis of shape (Jones, Smith, & Landau, 1991), foods on the basis of colour (e.g., studies with monkeys by Santos, Hauser, & Spelke, 2001), and substances on the basis of material. Ellis and Oakes (2006) presented 14-month-old infants with objects that could be categorized by shape (balls vs. blocks) or material (soft vs. hard). Infants who were more acquainted with categorization at a superordinate level or who had larger receptive vocabularies categorized the objects by material as well as by shape, in a flexible way, whereas other infants tended, primarily, to form categories based on shape.

To date, studies focusing on object consistence were conducted mainly in the developmental areas, while the present work investigates the role of object consistence in adults. The question we intend to address in this work is whether information on object consistence is automatically activated in adults across different categorization tasks and different response modalities. In other words, we hypothesize that, while observing images of objects, we simulate an interaction with them, and we predict that this simulation is so fine-grained as to be sensitive to differences in object consistence. As previously seen, the simulation theory (Gallese & Goldman, 1998; Jeannerod, 2007) has its neurophysiological basis in the discovery of two kinds of visuo-motor neurons: canonical and mirror neurons (see Gallese et al., 1996; for a review, see Rizzolatti & Craighero, 2004). Of particular relevance for our aims are canonical neurons, which discharge during both the execution of specific object-directed actions and during the mere visual presentation of graspable objects. In our work we also intend to explore whether information on consistence is used to distinguish between different kinds of concepts (artefacts and natural objects).

To address these issues we devised three experiments. Across the experiments we used images of common graspable objects (for the complete list, see Appendix A), in order to avoid the influence of linguistic information, and a categorization task, manipulating the relevance of consistence to the task. More specifically, in Experiment 1 participants were required to decide whether pictures of objects represented hard or soft objects, thus consistence was relevant to the task; in Experiments 2 and 3 the task consisted in categorizing objects into artefacts or natural objects, thus it did not require consistence to be directly accessed. We also manipulated the response modality as follows. In Experiments 1 and 2 we asked participants to respond by grasping either a soft or a hard tennis ball, in order to enhance information related to object manipulation. The use of a soft vs. a hard ball was manipulated between blocks but within participants, because we thought that the sensitivity to such a subtle tactile dimension could be detected only by reducing the variability across subjects. In Experiment 3 we required participants to respond by using a simple key pressure, assuming that this modality of response should not directly activate information on object consistence.

On the basis of this theoretical framework, we advanced the following predictions. Across all experiments we predict a main effect of consistence and an interaction between consistence and kind of object. If we simulate interacting with objects while seeing them, then hard objects should be processed faster than soft ones, as in real life, since the kind of grip that hard objects evoke requires less time to be executed, it is less complex, and it does not require the hand to surround the object for a whole. In addiction, this effect of consistence should be more salient for artefacts than for natural objects. Moreover, the comparison between the three experiments will allow us to verify whether consistence is activated independently of the kind of task and from the response modality. If consistence is activated independently of the kind of task, we should obtain the same results across the three experiments, that is, the effect should emerge even in tasks which simply require the categorization of objects into artefacts and natural objects. If consistence is activated independently of the response modality, we should obtain the same results across the three experiments, that is, the effect should emerge even in tasks implying a simple key pressure as response modality. Finally, by comparing the three experiments we aim to explore to what extent participants are sensitive to the response modality. Namely, participants could be sensitive either to fine details or to broad differences concerning the modality of response. If they are sensitive to fine details, a difference should emerge between grasping the soft ball, grasping the hard ball, and pressing the key to answer; if they are sensitive to broad differences we should only find a difference between ball grasping and key pressing.

The analyses of variance (ANOVA) on correct response times showed, first of all, that we are sensitive to differences in object consistence and that this sensitivity to consistence occurred in all three experiments, across different categorization tasks and was not modulated by response modalities. Namely, participants detected differences between hard and soft objects independently of whether the task required them to categorize objects by consistence or to categorize them by object kind (artefacts vs. natural objects), and independently of whether they had to respond by pressing a key while grasping either a soft or a hard ball or to respond by pressing a key on a keyboard without holding balls. Given that differences in consistence are not due to factors such as familiarity, visual complexity or typicality (controlled by means of three ratings), the advantage of hard over soft objects seems to be due to the simulation of a real interaction with an object rather than to a simple semantic association between a property and an object. This is in line with the idea that the kind of grip that hard objects evoke requires less time to be executed and it is less complex (Ehrsson, Fagergren, Jonsson, Westling, Johansson, & Forssberg, 2000). However, this effect of consistence was present with artefacts, rather than with natural objects. It is therefore plausible that it is linked to grasping for using an object rather than to grasping for simply manipulating it (for a discussion on this issue, see Borghi et al., 2007).

Secondly, differences in response modality as well as in task change the way we represent artefacts and natural objects. When the task requires subjects to focus on single exemplars (Experiment 1), our results, in line with the Cascade model (Humphreys, Riddoch, & Quinlan, 1988; Humphreys & Forde, 2001), show that natural objects are processed slower than artefacts. This should be due to the fact that identifying individual category exemplars is more demanding for natural objects than with artefacts, since natural objects are more similar to each other than artefacts, thus they “compete” more for identification. Our results were also in keeping with the PACE (pre-semantic account of category-effects) model, a refined account of the Cascade model (Gerlach, Law, Gade, & Paulson, 2000; Gerlach, Law, & Paulson, 2004, 2006; Gerlach, 2009). According to PACE, category effects do not depend only on differences in structural similarity between categories but also on the kind of task. Thus, PACE accounts for our results as it predicts that natural objects are only disadvantaged if the task requires a fine-grained perceptual differentiation among items. When the response enhanced manipulation (Experiment 2), responses did not differ between artefacts and natural objects, because participants did not need to process the single exemplars but performed a broad categorization task. This should lead to an advantage of natural objects over artefacts, but we found no difference between the two categories. This is probably due to the fact that responding while holding balls enhances manipulability, and this might interfere with the processing of natural objects more than with the processing of artefacts. Finally, when the response did not enhance manipulation (Experiment 3), artefacts were categorized slower than natural objects. In keeping with the Cascade model, natural objects are faster with a categorization task which does not require the access to single exemplar. This result also supports the view according to which artefacts activate both manipulation and function information, while natural objects activate only manipulation information (Borghi et al., 2007; Vainio et al, 2008).

Third, and more crucially, we found that consistence helps to disentangle different kinds of objects. More specifically, we detect differences in consistence more clearly within artefacts than within natural objects. This might be due to the fact that artefacts’ characteristics are perceived as more clearly defined compared to those of natural objects. However, the fact that the interaction between consistence and object category is maintained across tasks that require subjects to focus either on the single exemplars

(Experiment 1) or on superordinate categories (Experiments 2 and 3) suggests that the result is specific for this property, consistence, and it cannot depend simply on the fact that artefacts have higher within category differences.

We also performed a follow up study on consistence with school-age children (Anelli et al., in preparation b), with the aim to verify whether knowledge on consistence emerges and thus is already present in kids. We used the same method as with adults, using a simplified task: the children had to perform either a natural/artefact categorization task or to decide whether the object was smooth or hard, by pressing a key on a keyboard without holding balls.

Preliminary results showed that there were no differences between adults and children performance when the task required a natural/artefact discrimination, while a different performance were registered when a hard/soft discrimination was necessary. Indeed, in the first task children pay attention to motor-perceptual features (i.e. consistence), while in the second one consistence seems do not influence the performance, in line with the idea that knowledge on consistence is not yet completely present in school-age children.

This kind of study has implications for research on object affordances, since the sensitivity to object consistence shows that visual stimuli activate previous sensorimotor interactions with the objects. The results have novel implications for work on categorization, as they clearly showed that consistence represents an important cue which helps to disentangle information associated with artefacts and natural objects, and it might be relevant to characterize artefacts. Therefore, models of categorization should be extended to include this very important property.

2.4 Affordance effect and motor resonance

Briefly resuming what has been previously highlighted, many studies have shown that objects observation evokes simple actions, such as reaching and grasping. Therefore, the notion of affordance, originally proposed by Gibson (1979), can be defined in term of potential action patterns activated during the vision of objects. As for the neural basis of affordances, canonical neurons discovered in the monkey ventral premotor cortex (Murata et al., 1997) seem to have the function of representing objects as potential action patterns. Brain activation studies in humans confirms that the mere observation of a graspable object activates components of the action observation network, namely the dorsal premotor cortex and the anterior intraparietal sulcus (Grafton et al. 1997), and that the influence of the object on grasp planning is within this network (Grèzes et al. 2003).

Moreover, several behavioural studies used compatibility paradigm and demonstrated that objects observation can activate a motor simulation and evoke overt reaching and grasping movements (e.g., Borghi et al., 2007; Vainio et al., 2008; for a review, see Borghi & Cimatti, 2010). Since this last point is particularly relevant for the purposes of this thesis, now I would present in more detail the cited studies.

2.4.1 Compatibility paradigm and motor simulation

Borghi and colleagues (2007) investigated whether seeing objects automatically leads to an activation of information about how to manipulate them. Participants were required to observe on the computer screen photographs of objects, that could be manipulated either with a power or a precision grip, and they had to classified target-objects as artefacts or natural. Target-objects were preceded by primes showing photographs of hands in grasping postures (precision or power grip). Results showed a congruency effect between the prime-hand posture (precision vs. power) and the kind of grip required to grasp the target-object (precision vs. power). This effect was found only when the experiment was preceded by a motor training phase in which participants imitated the gestures displayed in the hand-pictures. The result suggests that motor information is automatically activated by visual stimuli; however, participants have to be trained to reproduce the primes-postures before the categorization task, in order to induce a stronger association with the hand-postures they would adopt to interact with specific target-objects, and thus obtain a specific motor priming. Vainio et al. (2008) tried to further clarify to what extent, during object identification, occurs the processing of motor aspects of an object. The authors used a modified version of the paradigm of Borghi et al. (2007), replicating the study with video-clips instead of static hands images and without asking to participants to perform a motor training phase. Results showed a stronger congruency effect between the hand posture and the grip evoked by objects. Thus, simulating the grasp action in the training phase (Borghi et al., 2007) and observing dynamic grasping (Vainio et al., 2007) may bear similar influences on effect production. When the hand primes are static, the training might be necessary for the reactivation of gestures that are primed by the observed hand in an action-observation matching system. In contrast, observation of dynamic grasping may directly lead to this activation of gestures in the same system. Taken together, these two behavioral studies highlight that when a hand in potential interaction with an object is observed motor information emerges, leading to a facilitation effect and a motor simulation (for a review, see Borghi & Cimatti, 2010).

Overall, both behavioral and brain imaging findings clearly indicate that perceiving affordances leads to the activation of specific motor programs in observers. The possibility for a given feature to evoke a motor behavior (e.g., a grasping-like behavior) relies on the sensori-motor coupling that allows an onlooker to map the feature onto the motor possibilities of one’s own motor repertoire (Costantini & Sinigaglia, 2012). This phenomenon occurs both at the neural and at the behavioral level and can be interpreted as activation of a motor simulation. Referring to what claimed in the previous chapter, simulation means that the same sensorimotor systems are activated both on-line during interaction with objects and off-line during object observation, even if in the last case there is not an execution of overt movements (e.g., Jeannerod, 2006; Gallese, 2009).

2.4.2 Characteristics of resonance mechanism

Other studies have revealed further features of this motor simulation system. For example, they suggested that the mirror system activity specifically codes motor actions of a biological agent: indeed, less mirror system activity, in other words less motor resonance, was registered during the observation of an artificial hand action than during the observation of a real hand action (Perani, Fazio, Borghese, Tettamanti, Ferrari, Decety, & Gilardi, 2001; Tai, Scherfler, Brooks, Sawamoto, & Castiello, 2004). Moreover, biomechanically impossible actions did not activate the mirror system (Stevens, Fonlupt, Shiffrar, & Decety, 2000). Buccino and colleagues (Buccino, Lui, Canessa, Patteri, Lagravinese, Benuzzi, Porro, & Rizzolatti, 2004a) compared the actions of non-conspecifics, and found that actions belonging to the motor repertoire of the observer were mapped on his/her motor system. Motor resonance increases when both participants and observed actor share the same culture (Molnar-Szakacs, Wu, Robles, & Iacoboni, 2007) and perspective (Bruzzo, Borghi, & Ghirlanda, 2008). On the whole, these results suggest that our resonance system is sensitive to the degree of correspondence between the observed action and the motor capability of the observer.

It is important to highlight another relevant point: the role of individual differences. Each person's motor repertoire is constrained not only by common musculoskeletal anatomy, but also by the skills that person has learned (Grèzes & de Gelder, 2008). A particular action may be included in the motor repertoire of a trained expert but not in the motor repertoire of someone who has not been so trained. Different researchers used acquired motor skills as an instrument to investigate the tuning of the brain's mirror mechanisms. Indeed, groups of individuals with different acquired motor skills were tested to verify whether the brain's system for action observation is precisely tuned to the individual's acquired motor repertoire. In this regard, some interesting researches demonstrated that the activation of a motor simulation is possible only when performing a given sequence of actions is part of participants' motor competence or, stated differently, that individuals are selectively sensitive to those actions that are related to and share features with their actions (e.g., Calvo-Merino et al., 2005). As mentioned in Chapter 1, several evidence derives from researches on motor expertise. For example, different studies have demonstrated that resonant mechanisms are activated during observation of others dancing, playing basketball, or climbing, and that this motor resonance is stronger when expert athletes rather than novices observe other experts (e.g., Calvo-Merino et al., 2005, 2006; Aglioti, Cesari, Romani, & Urgesi, 2008; Cross, Kraemer, Hamilton, Kelley, & Grafton, 2009; Pezzulo, Barca, Bocconi, & Borghi, 2010).

More specifically, in a fMRI study Calvo-Merino et al. (2005) studied experts in classical ballet and experts in capoeira dancing. Greater activity in the mirror areas was found when dancers watched their own dance style (i.e., when classical ballet dancers watched ballet moves and capoeira artists observed capoeira moves). Thus, the motor system was more strongly engaged during action observation when participants already had a specific motor representation of the action they observed. However, this effect could also be due to dancers' higher visual familiarity with a kind of movement and not to a real motor simulation. These concerns were directly addressed in a control-study (Calvo-Merino et al., 2006). Expert female and male classical ballet dancers watched movies of gender specific ballet moves. The rationale behind this study was that male and female dancers should have the same amount of visual exposure to all movements, because they do their training together, hence the critical manipulation was watching movements performed by male or female. Results showed a stronger activation in motor areas and a larger motor resonance effect when dancers observed movements performed by other classical ballet dancers of their own gender, thus from their own motor repertoire, compared to opposite-gender moves that they frequently saw but did not perform. Thus, participants seem to translate the observed movements into their specific motor capabilities. Furthermore, this finding constitutes a proof that dancers not only mentally simulated but also predicted the upcoming part of a move they observed on the basis of their own motor knowledge, as demonstrated by the activation of the cerebellum which is involved in precise prediction (Wolpert, Doya, & Kawato, 2003).

In the same vein, in a psychophysical study Aglioti et al. (2008) showed that elite basketball players are able to predict the success of free shots at a basket earlier and better than expert observers and novice players. This advantage for experts has been attributed to their higher capability to read body kinematics in the early movement phases and consequently to make prediction.

Finally, in a behavioral study Pezzulo et al. (2010) showed to expert and novice rock climbers three different routes (easy, impossible, and difficult). The performance in a subsequent recalling test showed no differences between experts and novices on the easy and impossible routes, whereas the performance of experts was better than that of novices on the difficult route. Also in this case, the simulation process appears to be modulated by motor repertoire and expertise.

To conclude, to date several evidence clearly demonstrates that our brain “resonates” when we see others performing actions. This resonance mechanism is modulated by the similarity between the actions we observe and the actions we are able to perform, and this demonstrates that the perceptual system is tuned to one’s own motor capabilities. What has been presented in this chapter will be useful in the next one, given that the Study 1 is focused on investigating fine-grained resonant mechanisms with dangerous affordances.

CHAPTER III

STUDY 1:

MOTOR RESONANCE WITH DANGEROUS AFFORDANCE

3.1 Introduction

In order to survive, humans must become able to respond adequately to the invites objects offer to them. For example, they need to be able to discriminate between objects that can be potentially source of danger or pain (from now on dangerous object) and objects they can approach without any risk (from now on neutral object). Namely, they have to learn to grasp useful objects, such as glass and tomato, and to avoid grasping potentially dangerous objects, such as broken glasses and cactus. Should also be considered that information on potential risks objects evoke might conflict with motor actions activated while observing objects.

As widely discussed in Chapter 2, since the seminal book of Gibson (1979), many behavioural and neuroscience studies have shown that observing objects, and particularly tools, activates affordances evoking motor responses (e.g., Ellis & Tucker, 2000; Martin, 2007; Bub & Masson, 2010), and that even comprehending words activates the affordances of the objects they refer to (e.g., Glenberg & Robertson, 2000; Gentilucci, 2003; Borghi & Riggio, 2009; Costantini, Ambrosini, Scorolli, & Borghi, 2011). In the last decade research has shed new light on the role played by affordances. Behavioural experiments have shown that objects evoke specific action components (i.e. micro-affordance, Ellis & Tucker, 2000): for example, when observing an apple or a bottle, participants are facilitated when they have to respond by mimicking a power rather than a precision grip (Tucker & Ellis, 2001). A number of computational models have been proposed (e.g., Sahin, Cakmak, Dogar, Ugur, & Ucoluk, 2007; Caligiore, Borghi, Parisi, & Baldassarre, 2010; Borghi, Di Ferdinando, & Parisi, 2011). In the field of cognitive psychology and cognitive neuroscience, a major difference between the Gibsonian view and recent studies is that, in contrast with the externalist perspective promoted by Gibson, current research takes into account how affordances are represented in the brain. However, the majority of studies focus on affordances in adults, with a few notable exceptions (e.g., Rochat, 1987; Smith, 2000, 2005).

In contrast, the present study (Anelli et al., in press b; Anelli et al., under review) focuses on how affordances develop as it aims at investigating whether both adults and school-age children are sensitive to differences in object typology (i.e. between neutral vs. dangerous objects) and object category (i.e. between artefact and natural objects), and whether they resonate while observing a hand priming an object.

As claimed by Sahin and colleagues (Sahin et al., 2007), we perceive affordances from multiple perspectives. Specifically, we perceive not only the affordances that the environment offers to us, but also the affordances that the environment offers to others. The second type of affordances (i.e., the affordances from an observer perspective) appears when we observe the potential interaction of someone else (human, animal or even robot) with the environment. In a recent study, Costantini and colleagues (Costantini, Ambrosini, Tieri, Sinigaglia, & Commitieri, 2010) have shown that participants respond to objects affordances when objects are located in their own peripersonal but not in the extrapersonal space, unless they are located in the other’s peripersonal space. This indicates that we are sensitive to objects’ affordances and at the same time that we are able to see objects from the point of view of another person. Consistently with the idea that we perceive affordances from an observer perspective, behavioral studies with a priming paradigm have shown that when the target-object is preceded by a hand prime displaying a congruent grip, categorization responses are facilitated (e.g., Borghi et al., 2007; Vainio et al., 2008). As more fully described in the previous chapter (see section 2.4.1), these studies highlight that when observing a hand in potential interaction with an object motor information emerges and a facilitation effect is found (for a review, see Borghi & Cimatti, 2010).

Provided that observing graspable objects, particularly when preceded by an action prime, evokes a motor response, what happens when dangerous objects are seen in interaction with a hand? Different TMS studies on empathy for pain, a topic introduced in Chapter 1 (see section 1.5.4), have investigated passive responses to pain observation (e.g., Avenanti, Bueti, Galati, & Aglioti, 2005; Avenanti et al., 2006). The results of such researches showed that, after watching a needle inserted deep into a model hand, a selectively inhibition was registered. Indeed, the significant MEPs amplitude decreases were specific not only for the observed body part (i.e. for the hand and not for the foot), but also for the particular muscle observed, compared to a non-body object (tomato) or to a tactile stimulation (innocuous cotton bud control). Thus, pain observation leads to a specific corticospinal inhibition, similar to directly-experienced painful stimulation (e.g., Le Pera, Graven-Nielsen, Valeriani, Oliviero, Di Lazzaro, Tonali, & Arendt-Nielsen, 2001; Farina, Tinazzi, Le Pera, & Valeriani, 2003). This finding suggests a resonant activation of pain representations in the onlooker's sensorimotor system.

Not only neural, but also behavioral evidence (Morrison et al., 2007) has demonstrated a specific influence of pain observation on overt motor responses. More specifically, observing a video of a needle penetrating a hand speeded withdrawal movements (key releases) and slowed approach movements (key presses); this difference was not present when participants observed a cotton bud touching a hand or when both the needle and the cotton bud penetrated or touched a sponge rather than a hand.

To this point, it is important to specify what we mean by the notion of empathy in this study. Following Morrison et al. (2007), we can distinguish between pain empathy and pain recognition. “We regard pain empathy as a compassionate affective state which the observer experiences on behalf of the sufferer, and which may result in prosocial actions. Pain recognition [is] a basic appraisal of the pain-related nature of the sufferer’s situation. Although pain recognition may be necessary for empathy, it is not sufficient for it, and may occur independently of empathy in day-to-day contexts. Nevertheless, pain recognition may involve affective evaluation and motor response modulation” (Morrison et al., 2007, p. 415). In line with this distinction, previous studies concern the influence of pain observation on motor responses, thus pain recognition. It is also important to clarify that adopting the notion of empathy for pain we intend to refer to phenomena of emotional contagion, not to the cognitive aspects of empathy. Nummenmaa and colleagues (Nummenmaa, Hirvonen, Parkkola, & Hietanen, 2008) explain that simulating others’ emotional states can represent a special case of empathy, i.e. emotional empathy, which differs from cognitive empathy. Indeed, emotional empathy (or emotional contagion) involves the mirror neuron system more than cognitive empathy, and is at the basis of the motor resonance for others.

Overall, previous studies provide clear evidence, pertaining both behavioural responses and underlying neural mechanisms of empathy for pain (namely, pain recognition and emotional contagion). However, to our knowledge they investigate only cases in which pain is passively induced by an object (e.g., the needle), and in which there is a direct interaction between the painful object and the hand. Our study, instead, focuses on the resonant mechanisms elicited when observing somebody (a hand) actively preparing an action toward a dangerous object and when the interaction between the hand prime and the object is not direct but potential.

A further line of research is relevant to the issue addressed in this study. Recent neuroscience works have provided evidence of a motor resonance effect triggered by the observation of others’ actions. As already discussed in the previous chapters, a variety of brain imaging results have shown that, the higher the similarity between the observed motor program and the motor program participants are able to execute, the more the mirror neuron system is activated (Calvo-Merino et al., 2005, 2006; Aglioti et al., 2008; Calvo-Merino, Ehrenberg, Leung, & Haggard, 2010; Pezzulo et al., 2010). A good example is given by neuroimaging and behavioural studies on action observation on expert dancers. For example, in a series of experiments Calvo-Merino and colleagues demonstrated that neural activity in premotor and parietal areas was stronger when dancers viewed moves from their own motor repertoire compared to opposite-gender moves that they knew but did not perform.

To our knowledge, the only study in which motor resonance was investigated while observing different kinds of hands interacting with painful stimuli is a recent TMS work (Avenanti, Sirigu, & Aglioti, 2010) that explored emphatic brain responses in white and black participants while observing the pain of ingroup or outgroup members (i.e., of members of the group to which they belong or not). Perceiving painful stimulations on ingroup members led to an immediate resonance (i.e., an inhibition of the onlookers' corticospinal system) while responses to outgroup members' stimulations were less automatic.

On the behavioural side, evidence on motor resonance during observation of different kinds of hands (e.g., in different postures, in different perspectives, or belonging to different populations) has been found with priming paradigms. Bruzzo and colleagues (Bruzzo et al., 2008) demonstrated that the similarity between observed hand primes and participants own hands facilitated judgements on action plausibility: specifically, responses were faster when participants wore a glove and observed gloved hands, and when they observed hands in their own perspective rather than in an allocentric perspective. Liuzza and colleagues (Liuzza, Setti, & Borghi, 2012) recently investigated motor resonance in children. Children were required to judge the weight of an object primed by a child or an adult hand in an action-posture (grasp) or in a non action-posture (fist). Their responses were faster when the object was preceded by a grasping hand and when the prime-hand was a child's hand rather than an adult's one. In a similar vein, Ranzini and colleagues (Ranzini, Borghi, & Nicoletti, 2011) investigated action- and object-related motor cueing effects, by means of a hand-cued line bisection task in which human and robotics hands were displayed. Relevantly to the present work, they found a stronger lateralization effect with biological than non-biological stimuli indicating a higher motor resonance effect with human than with robotic hands.

In sum, so far Avenanti and colleagues (Avenanti et al., 2005, 2006 2010) have provided evidence of a resonant mechanism while observing different kinds of hands interacting with painful stimuli. However, in these studies pain was passively induced by the object (the needle), and participants could observe the direct interaction between the hand and the needle. In our study we intend to explore resonant mechanisms with a priming paradigm, during active action preparation, when the hand and the object do not interact. Thus, the present work investigates at a functional level the mechanisms occurring during observation of a prime given by a hand or by a control object followed by objects that might be dangerous or provoke pain. To the best of our knowledge, no previous study has investigated active responses to dangerous stimuli and the effects of social variables, such as gender and age of participants, on this kind of task. In addition, even if the study by Liuzza et al. (2012) confirms the existence of motor resonance in children, to our knowledge so far nobody has explored how motor resonance develops from childhood to adult age.

To investigate this complex issue we used a priming paradigm, presenting children (Experiment 1 and Experiment 2) and adults (Experiment 3) with different kinds of primes followed by different kinds of objects. We presented five different kinds of hands-primes: four human hands and a robotic hand. The human hands were orthogonally organized as follows: there were two male hands and two female hands, of which two hands were in a grasping posture and two were in a not grasping (i.e., static) posture. The robotic hand was included to verify whether a difference was present between responses to human and non-human hands (i.e., between biological and non-biological primes). Beside these five hands-primes, a control stimulus was presented, given by an object of low visual complexity and very easily recognizable, i.e. a brick, in order to check whether the presentation of any kind of prime might influence the participants' responses. Overall, the primes were selected in order to manipulate the gender of the observed prime-hand (male vs. female hands) and to suggest or not a potential action (grasping vs. static hands).

The presentation of the prime was followed by the appearance of a target-object. Overall, we selected sixteen target-objects. In order to manipulate the object typology and the object category, the objects were orthogonally organized as follows: we used eight neutral and eight dangerous objects, of which eight objects were artefacts and eight natural objects.

The aim of our study is twofold. First, we intend to verify how responses to objects and sensitivity to fine object characteristics (i.e. object typology and object category) develop. Specifically, we investigate the ability to differently perceive and process objects that can be potentially source of danger or pain for us (dangerous object) and objects that we can approach and interact without any risk (neutral object). We did not distinguish between potential pain or threat, since we were interested in motor resonance while observing objects or entities that can potentially provoke pain, independently from their being active or passive. Indeed, even for animals it would be difficult to distinguish between those representing an active threat and those potentially dangerous but typically more passive: for example, would a scorpion considered as an active threat or as responding only when attacked? We hypothesize that all graspable objects activate a facilitating motor response; however, in the case of dangerous objects the response might be blocked, generating an interference effect. In other words, observing dangerous and painful objects would evoke aversive affordances, in line with the results of Morrison and colleagues (Morrison et al., 2007). As to the developmental trajectory of this effect, we predict that the capability to distinguish object typology (i.e. between dangerous and not dangerous objects) emerges quite early in development, as it is crucial from an adaptive point of view, whereas the capability to differentiate motor responses depending on fine-grained differences related to the object category (i.e. between artefact and natural objects), for example activating functional information for artefacts, emerges later.

Second, we aim to investigate how motor resonance develops. Namely, this issue concerns whether both children and adults are sensitive to the affordances and the potential dangers offered by the objects in the environment to others. In writings of Gibson, support for the observer perspective can also be seen. While describing the nature of the optical information for perceiving affordances, Gibson (1979) mentions that it is required for a child to perceive the affordances of things in the environment for others as well as itself: “The child begins, no doubt, by perceiving the affordances of things for her, for her own personal behavior. But she must learn to perceive the affordances of things for other observers as well as herself” (Gibson, 1979, p. 141). We hypothesize that, with age, participants become progressively more careful to the agent who may interact with object, namely responses are modulated by details of the hands as well as of the motor program the hand evokes. More specifically, if a general motor resonance phenomenon occurs, then we should obtain a difference between responses to the biological primes (i.e., human hands) and the non-biological primes (i.e., robot hand and brick). If this motor resonance effect is sensitive to fine-grained aspects, then we should find: first, a gender-dependent motor resonance, namely male participants should resonate more with male hand-primes, and female participants with female hand-primes; second, a sensitivity to the relationship between the hand posture and the action, namely we should find a difference in responding to the grasping compared to the static hand posture.

Interestingly, the choice of a priming paradigm could allow us to investigate the timing of two different mechanisms, one possibly related to the activation of the mirror neuron system, triggered by the observation of the hand, and the other to the canonical neuron system, activated by the presence of the object (Liuzza et al., 2012). Two possibilities are open. The first is that observing the hand-prime induces to prepare an action, possibly through the mediation of the mirror neuron system, and that later, on appearance of the object, either a facilitating or a blocking mechanism induced by the object intervenes. This leads to the prediction that, the higher is the motor resonance induced by the observed prime, the more a general facilitation effect should be present. The second possibility is that the prime, together with the object that follows, activates a specific motor program. This leads to the prediction that, the more similar the prime is to the participant's own hand, the slower the responses with dangerous objects should be. To clarify: the more we identify ourselves with the person we observe, the more we are careful in dealing with dangerous objects.

3.2 Experiment 1

The aim of the first experiment is twofold. First, we intend to investigate whether school-age children are sensitive to differences in object dangerousness (i.e. neutral vs. dangerous objects) and object category (i.e. artefact vs. natural objects) as well. Specifically, we predict an interference effect with dangerous objects, resulting in slower response times with dangerous compared to neutral objects.

Second, we are interested in exploring whether and to what extent children resonate while observing a hand priming an object. If observing a hand prime evokes motor resonance, then responses should differ when observing a biological prime (i.e. a prime more similar to the participants hand, a human hand) compared to a non biological one (i.e. a robotic hand and a control prime). Furthermore, the hands showed as primes belong to children of the same age of the participants. In addition, if children are sensitive to fine grained aspect of the action they observe, they should respond differently when observing grasping hands compared to static hands, and when observing hands of their own gender compared to hands of another gender. If the motor resonance effect induced by the prime is modulated by the presented object, then we should find that the higher similarity between the prime and the children's own hand causes an interference when the prime is followed by a dangerous object and a facilitation when followed by a neutral object.

To these aims, we run an experiment in which participants were required to distinguish between artefacts and natural target-objects, so that the object dangerousness was not relevant to the task.

3.2.1 Methods

3.2.1.1 Participants

Twenty-six participants (16 males and 10 females) with a mean age of 7.4 years (age range: 6 – 8 years) took part in the experiment. All subjects were right-handed and reported normal or corrected-to-normal vision. All were naive as to the purpose of the experiment and their parents gave informed consent.

3.2.1.2 Apparatus and stimuli

Participants sat in front of a 17-inch colour monitor (the eye-to-screen distance was approximately 50 cm). E-Prime 2.0 software was used for presenting stimuli and collecting responses.

The experimental stimuli consisted of sixteen colour pictures of living and non-living objects preceded by a prime, in order to enhance (grasping hand) or to reduce (static hand) aspects related to the action, so that a simulation effect was induced (see Appendix B for the complete list and the pictures of the stimuli, section B.1 and B.2). All the objects would be normally grasped with a power grip. There were four categories (dangerous-natural objects, dangerous-artefact objects, neutral-natural objects, neutral-artefact objects), with four objects for each class. Each target-object was preceded by one of the six primes: a grasping hand of a male child, a grasping hand of a female child, a grasping hand of a robot, a static hand of a male child, a static hand of a female child, a control stimulus (brick).

A rating was carried out in order to check whether the target objects differed in dangerousness. Forty-three raters were asked to evaluate the degree of danger and potential pain evoked by each object on a five-point Likert scale (with 1 = not dangerous/neutral object and 5 = extremely dangerous object). Response means were entered into a within-subjects 2 x 2 ANOVA with the following factors: *Typology* (neutral and dangerous) and *Category* (artefact and natural). The analysis revealed the main effect of *Typology* [F (1, 12) = 95.3, MSE = 0.24, p < .001]. This result demonstrated that the sixteen objects differed concerning danger and pain evoked, and it also showed that there was no difference between artefact and natural objects.

3.2.1.3 Procedure

Participants were required to decide as fast as possible whether the target-stimulus was an artefact or a natural object by pressing one of two designed keys. Half of the participants were required to make a right-hand key-response if the target was artefact and a left-hand key-response if it was natural, whereas the opposite hand-to-category arrangement was applied to the other half.

The experiment consisted of one practice block of 24 trials and one experimental block of 96 trials. Each trial (see Figure 3.1 for the experimental design) began with a fixation point (+) displayed for 500 ms in the centre of the screen. Then, a prime was shown for 200 ms, followed by a white screen (SOA) for 50 ms. Then, a target object was shown and remained on the centre of the screen until a response had been made or 2000 ms had elapsed. Both prime and target objects were centred on the screen. Their average size was 307 x 323 pixel. Participants received feedback on reaction time (RT) after pressing the right or the wrong key (the reaction time value or “Error”, respectively). The next trial began after the feedback disappeared. The order of conditions was balanced across participants. Overall the experiment lasted about 15 minutes.

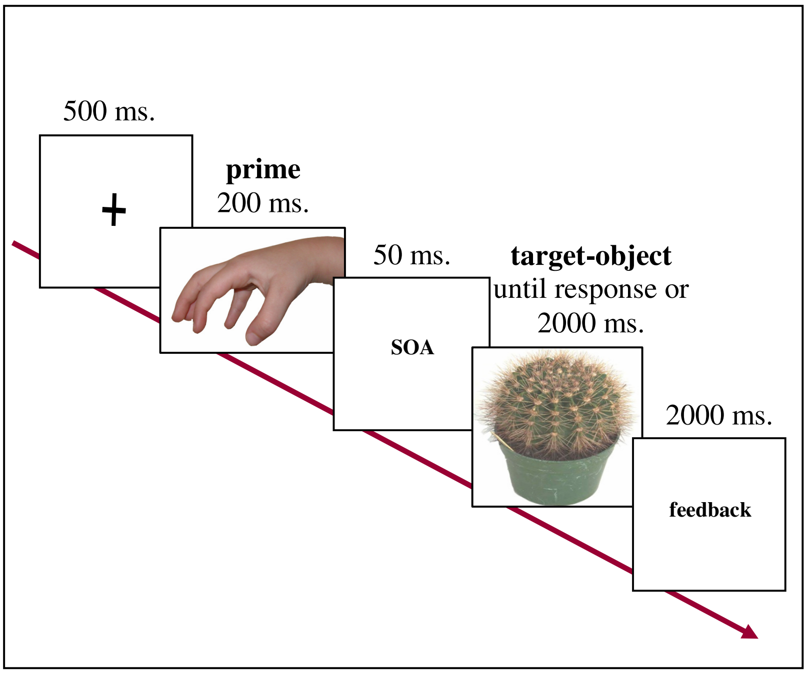


Figure 3.1 Study 1: experimental design, example of a trial**.**

3.2.2 Results

Reaction times (RT) for incorrect responses and RTs more than two standard deviations from each participant’s overall mean were excluded from the analysis. Error trials were excluded from further analyses (7 %). We decided to use ANOVA since it is widely used in RTs analyses in psychology and neuroscience. Indeed, compared to other statistics ANOVA is remarkably robust to deviations from normality, and slight deviations from normality typically characterize RTs distributions (for discussion on robustness of ANOVA, see Lindman, 1974; Boos & Brownie, 2004). The correct RTs were entered into a mixed 2 x 2 x 2 x 6 analysis of variance (ANOVA), with *Participant Gender* (male and female) as between participants factor, and *Object Typology* (neutral and dangerous), *Category* (artefact and natural), and *Prime* (grasping hand of a male child, grasping hand of a female child, grasping hand of a robot, static hand of a male child, static hand of a female child, control stimulus) as within participants factors. Fisher's LSD post-hoc tests were also conducted on significant interactions.

The analysis revealed the main effect of *Object Typology* [*F* (1, 24) = 5.12, *MSE* = 20273, *p* = .03], showing that responses were faster when the object was neutral and slower when the stimuli were dangerous (*M* = 694 vs. 721 ms, respectively), (Figure 3.2). Moreover, we obtained an effect of *Prime* [*F* (5, 120) = 2.27, *MSE* = 7561, *p* = .05]. The second main effect revealed that participants responded faster to the stimuli preceded by a human hand prime (i.e. a biological hand, 701 ms) and slower to the stimuli preceded by a robot hand and control stimulus (i.e. a non-biological hand, 722 ms). As revealed by the post-hoc test, response times were faster when the prime was the grasping hand of a female (*M* = 690 ms) than the grasping hand of a robot (*M* = 725, *p* < .01) or the control stimulus (*M* = 714, *p* = .04). Moreover, response times were faster when the prime was the static hand of a female (*M* = 699) than the grasping hand of a robot (*p* = .03), (Figure 3.3). Furthermore, there was a significant interaction between *Object Category* and *Participant Gender* [*F* (1, 24) = 4.28, *MSE* = 24434, *p* < .05]. The post-hoc test showed that males responded faster to natural objects and slower to artefacts objects (*M* = 686 vs. 720 ms respectively, *p* < .05), while there was no difference between natural and artefact objects as far as females were concerned (722 vs. 702 ms, respectively, *p* = .34), (Figure 3.4).

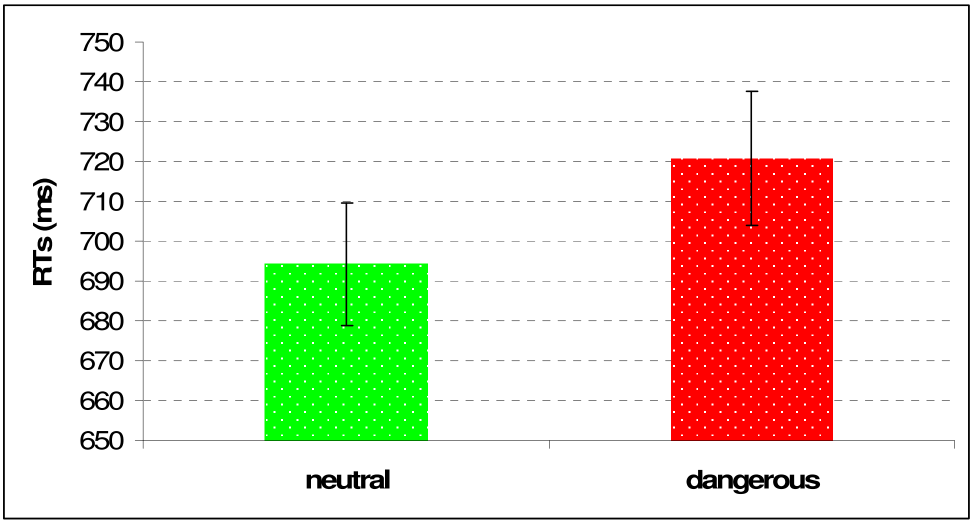


Figure 3.2 Study 1, Experiment 1: significant *Object Typology* effect for RTs, values are in ms and error bars show standard errors of the means.

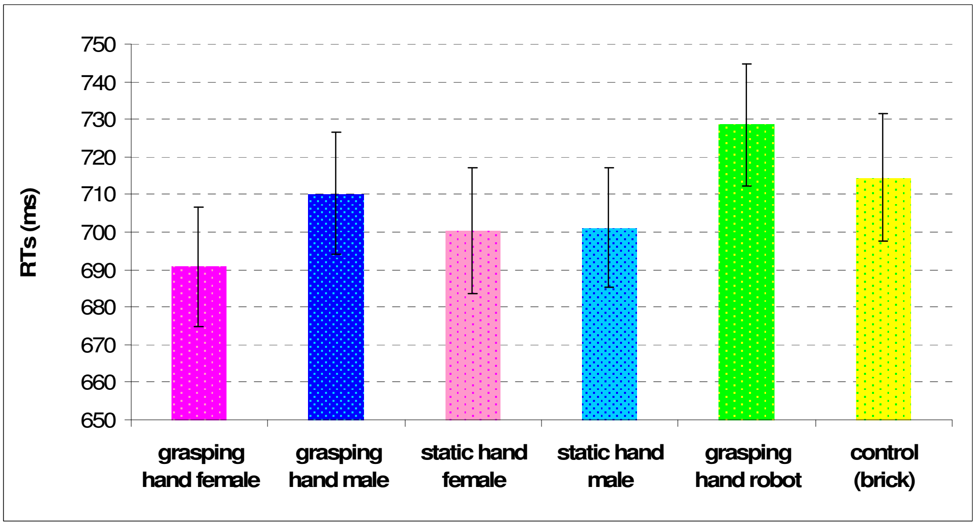


Figure 3.3 Study 1, Experiment 1: significant *Prime* effect for RTs, values are in ms and error bars show standard errors of the means.

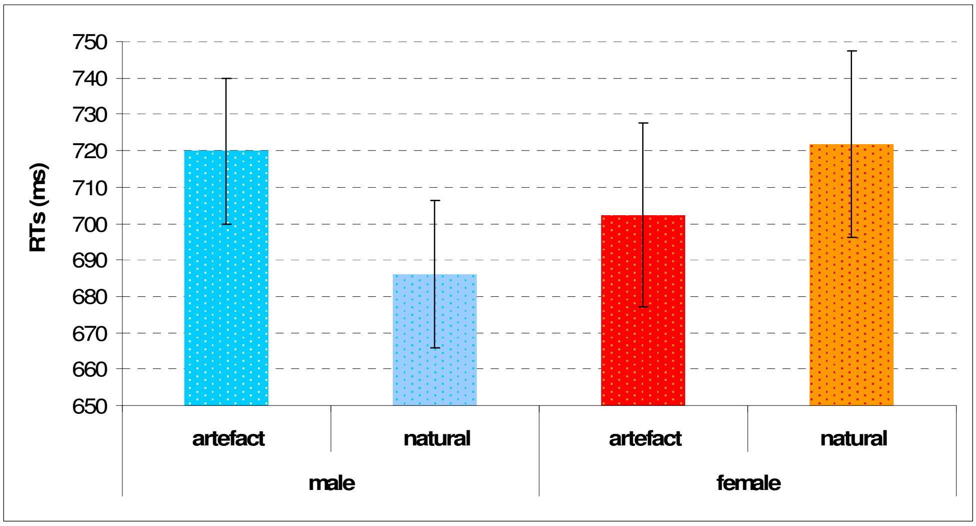


Figure 3.4 Study 1, Experiment 1: *Object Category* and *Participant Gender* interaction for RTs, values are in ms and error bars show standard errors of the means.

3.2.3 Discussion

Our results clearly demonstrate that school-age children are sensitive to the distinction between neutral graspable and dangerous objects. As revealed by the response time patterns, dangerous objects yielded longer RTs, probably due to the fact that a response was prepared, followed by a blocking mechanism leading to interference. To our knowledge, this is the first behavioural study demonstrating the capability to distinguish between neutral and dangerous objects in children.

Interestingly, children seem to be aware also of the difference between object categories. Specifically, males responded faster to natural objects than to artefacts. This result is in line with the literature (Borghi et al., 2007; Vainio et al., 2008; Anelli et al., 2010) and could be due to the activation of both manipulative and functional information with artefacts, while with natural objects only manipulative information is activated.

In addition, our results clearly show a motor resonance effect, since children are sensitive to the difference between actions performed by biological and non-biological agents. Overall, we found that children responded faster when the prime was a human hand compared to other stimuli (robotics hand and brick). We tend to interpret our result in terms of motor resonance: in line with common coding theories (e.g., Hommel et al., 2001) resonance would be higher when the similarity between the hand prime and the participant's hand is higher. Indeed, previous studies provided evidence of resonant effects, in both children and adults, showing with a variety of paradigms that, the higher the similarity between the hand (or the movements of the observed organism) and our own hand (or our movement), the more facilitation occurs (e.g., Ranzini et al., 2011; Liuzza et al., 2012). We tend to exclude that the advantage of human hand over the control stimuli was due to a sort of oddball effect, as human primes were twice as many as other primes. Indeed, each single prime was presented the same number of times (4 presentations in the practice block and 16 presentations in the experimental block). If we assume that participants were sensitive to the frequency of presentation of hand primes, then we should expect an advantage of the robotic hand over the brick (since all primes except the brick were hands), but there was not.

However, we must point out that children did not seem to be sensitive to other fine grained aspect of the action they observe, namely, there was no effect of gender congruency nor of kind of posture. There could be two possible explanations: first, we can have used, as biological primes, hands that do not differ enough by gender; namely, one could argue that there was not a clear difference between hands of a male child and hands of a female child, so that there can be a perceptual problem to discriminate the gender of the observed hand. Second, it can be possible that children are not yet sensitive to fine grained aspects of motor resonance such as gender.

3.3 Experiment 2

In order to disentangle whether the results of the Experiment 1 could be due to a perceptive problem of the primes hands (i.e., hands without a clear difference between hand of a male child and hand of a female child) or to a gender's lack of sensitivity, in the Experiment 2 we presented adult hands as primes (i.e., hands with a more clear difference between hand of a man adult and hand of a woman adult).

3.3.1 Methods

3.3.1.1 Participants

Thirty participants (16 males and 14 females) with a mean age of 8.2 years (age range: 6 – 10 years) took part in the Experiment 2. All subjects were right-handed and reported normal or corrected-to-normal vision. All were naive as to the purpose of the experiment and their parents gave informed consent.

3.3.1.2 Apparatus, stimuli, and procedure

The apparatus, stimuli, and procedure were the same used in Experiment 1 except for the following. We replaced the hands primes of children with hands primes of adults (see Appendix B, section B.3), so that each target-object was preceded by one of the following six primes: a grasping hand of a man adult, a grasping hand of a woman adult, a grasping hand of a robot, a static hand of a man adult, a static hand of a woman adult, a control stimulus (brick).

3.3.2 Results

Data were treated as in Experiment 1. Reaction times (RTs) for incorrect responses and RTs more than two standard deviations from each participant's overall mean were excluded from the analysis. Error trials were excluded from further analyses (6 %). The correct RTs were entered into a mixed 2 x 2 x 2 x 6 ANOVA, with *Participant Gender* (male and female) as between participants factor, and *Object Typology* (neutral and dangerous), *Category* (artefact and natural), and *Prime* (grasping hand of a man adult, grasping hand of a woman adult, grasping hand of a robot, static hand of a man adult, static hand of a woman adult, control stimulus) as within participants factors. Fisher's LSD post-hoc tests were also conducted on significant interactions.

In the ANOVA, the analysis revealed two main effects: *Object Typology* [F (1, 28) = 12.66, MSE = 6707, p < .01] and *Prime* [F (5, 140) = 2.75, MSE = 8673, p = .02]. Responses were faster when the object was neutral and slower when the stimuli were dangerous (744 vs. 765 ms, respectively), (Figure 3.5). The second main effect showed that participants responded faster to the stimuli preceded by a human hand prime (i.e. a biological hand, 745 ms) and slower to the stimuli preceded by a robot hand and control stimulus (i.e. a non biological hand, 773 ms). As revealed by the post-hoc test, response times were faster when the prime was the grasping hand of a woman (M = 748 ms) than the grasping hand of a robot (*M* = 774, p = .03) or the control stimulus (*M* = 771, p < .05), and when the prime was the grasping hand of a man (*M* = 746) than the grasping hand of a robot (*p* = .02) or the control stimulus (*p* = .04). Moreover, the responses were faster when the object was preceded by the static hand of a woman (*M* = 745 ms) than the grasping hand of a robot (*p* = .02) or the control stimulus (*p* = .03), and when the prime was the static hand of a man (*M* = 743) than the grasping hand of a robot (*p* = .01) or the control stimulus (*p* = .02), (Figure 3.6).

There were no other significant main effects or interactions. However, the interaction *Object Typology* and *Category* was marginally significant [*F* (1, 28) = 3.68, *MSE* = 8673, *p* = .07], and it suggested that responses to neutral objects were differently modulated by the category of the stimuli (i.e., responses to natural objects were faster than to artefacts, *M* = 733 vs. 754 ms, respectively), while in responses to dangerous objects a difference between natural and artefact objects (*M* = 769 vs. 762 ms, respectively) was not present.

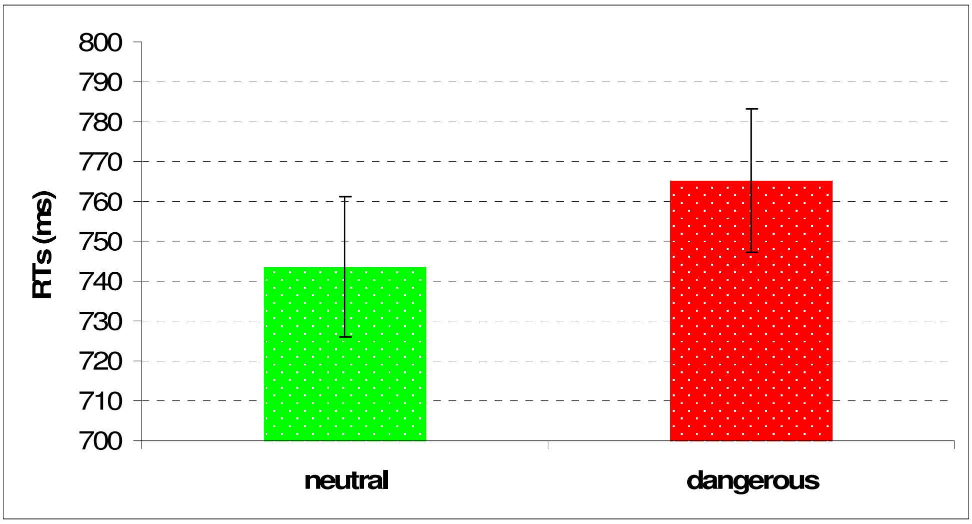


Figure 3.5 Study 1, Experiment 2: significant *Object Typology* effect for RTs, values are in ms and error bars show standard errors of the means.

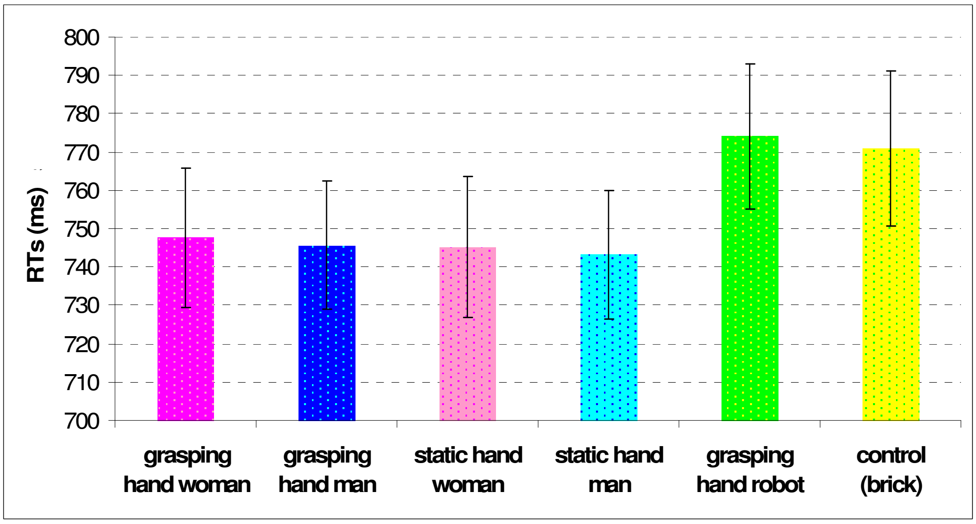


Figure 3.6 Study 1, Experiment 2: significant *Prime* effect for RTs, values are in ms and error bars show standard errors of the means.

3.3.3 Discussion

In line with results of Experiment 1, results confirmed that children were sensitive to the distinction between dangerous and neutral objects, as response times were slower with the first than with the second. However, no difference was found between artefacts and natural objects, although data suggest that this distinction begun to emerge.

In addition, also in the Experiment 2 we found evidence of a motor resonance effect, since children responded faster with biological than with non biological primes. However, they did not seem to be sensitive to fine-grained aspects of the action, since there was no effect of gender congruency and since response times did not differ depending on the kind of posture (grasping vs. static hand).

Furthermore, it is worth noticing that the two mechanisms, the motor resonance evoked by the prime and the motor response induced by the object observation, seem to be rather independent. Indeed, with the biological prime we found a facilitation, independently of the kind of object appearing later, and not an interference on appearing of dangerous objects. This testifies that probably there is an overall facilitation effect induced by observation of the hand action, and that interference occurs rather late, i.e. upon object presentation.

Overall, these results allow us to argue that data of the Experiment 1 seem to be due to a gender's lack of sensitivity in children and not to a perceptual problem of the primes hands, namely school-age children are not yet sensitive to fine grained aspects of motor resonance such as gender.

3.4 Experiment 3

In order to verify whether with age participants develop a finer sensitivity to objects and action characteristics, we used the same procedure of Experiment 2 but we assessed young adults.

3.4.1 Methods

3.4.1.1 Participants

Twenty undergraduate students from the University of Bologna (10 males and 10 females) with a mean age of 23.5 years (age range: 19 – 32 years) took part in the Experiment 3 for course credits. All subjects were right-handed and reported normal or corrected-to-normal vision. All were naive as to the purpose of the experiment and gave written informed consent.

3.4.1.2 Apparatus, stimuli, and procedure

The apparatus, stimuli, and procedure were the same used in Experiment 2.

3.4.2 Results

Data were treated as in previous experiments. Reaction times (RTs) for incorrect responses and RTs more than two standard deviations from each participant's overall mean were excluded from the analysis. Error trials were excluded from further analyses (4 %). The correct RTs were entered into a mixed 2 x 2 x 2 x 6 ANOVA, with the same factors and Fisher's LSD post-hoc tests as those of Experiment 2.

In the ANOVA, the analysis revealed the main effects of *Object Typology* [F (1, 18) = 9.25, MSE = 3263, $p < .01$]. As in the previous experiments, responses were faster when the object was neutral and slower when the stimuli were dangerous (500 vs. 515 ms, respectively), (Figure 3.7).There were no other significant main effects or interactions. However, the main effect of *Prime* [F (5, 90) = 1.79, MSE = 2136, $p = .12$], and *Prime* x *Participant Gender,* [F (5, 90) = 1.99, MSE = 2136, $p = .08$], were marginally significant. In line with the aim to investigate the gender-related resonance effect, we performed separated analyses by levels of *Participant Gender* in order to better understand these potentially significant results. The main effect of *Prime* was significant as far as the males group was concerned [F (5, 45) = 3.63, MSE = 2080, $p < .01$]. As revealed by the post-hoc test, participants responded faster when the prime was the grasping hand of a man (M = 473 ms) than with all other primes. More specifically, responses with the prime of the grasping hand of a man were faster than responses with the prime of the grasping hand of a woman (M = 501, $p <$. 01), grasping hand of a robot (M = 512, $p <$. 01), static hand of a man (M = 506, p = . 01), static hand of a woman (M = 506, p = . 02), and control stimulus (M = 504, p = .01), (Figure 3.8). The main effect of *Prime* was not significant for the females group [F (5, 45) = 0.26, MSE = 2191, $p = .93$] but there was a significant interaction between *Object Typology* and *Category* [F (1, 9) = 7.5, MSE = 941, $p = .02$]. The post-hoc test showed that responses to neutral objects were faster when they were natural and slower when they were artefacts (M = 498 vs. 518 ms, respectively, $p < .01$), while there was no difference between natural and artefact objects as far as dangerous objects concerned (523 vs. 520 ms, respectively, $p = .69$), (Figure 3.9).

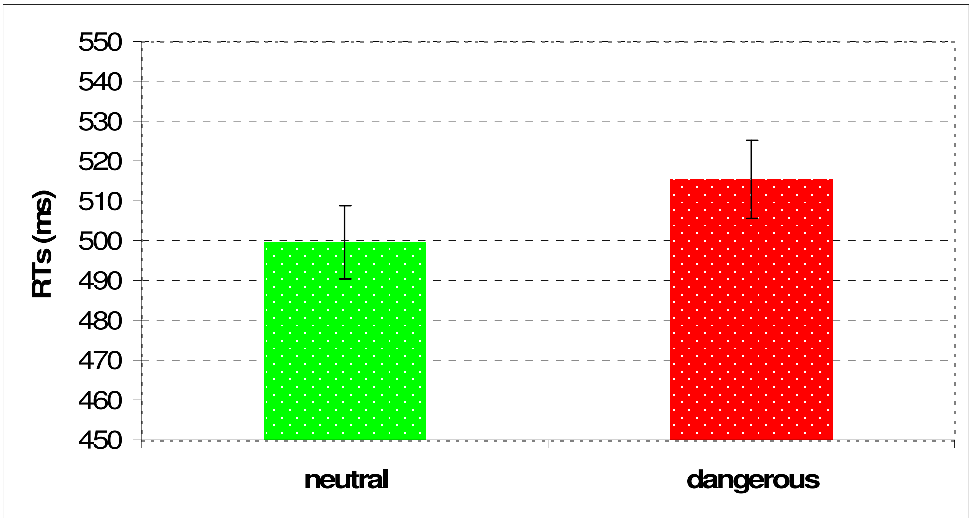


Figure 3.7 Study 1, Experiment 3: significant *Object Typology* effect for RTs, values are in ms and error bars show standard errors of the means.

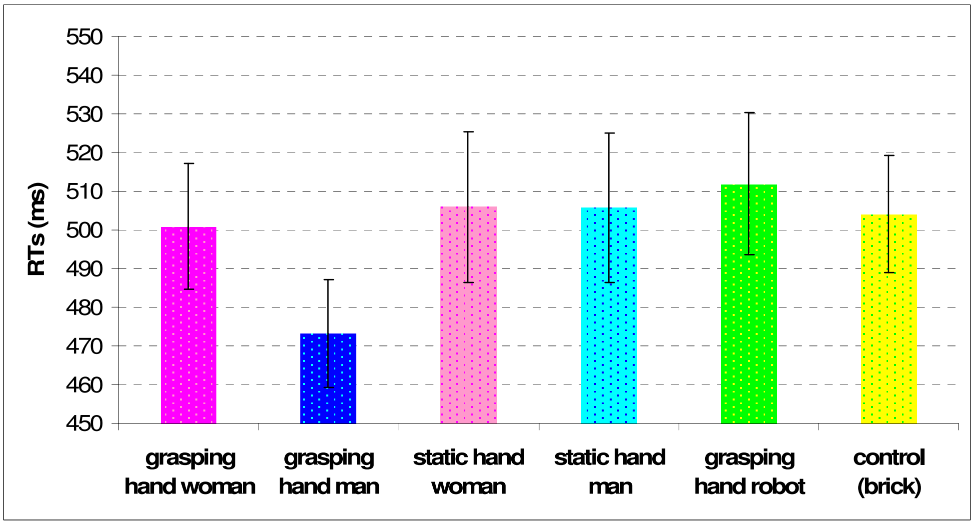


Figure 3.8 Study 1, Experiment 3: significant *Prime* effect for RTs (males group), values are in ms and error bars show standard errors of the means.

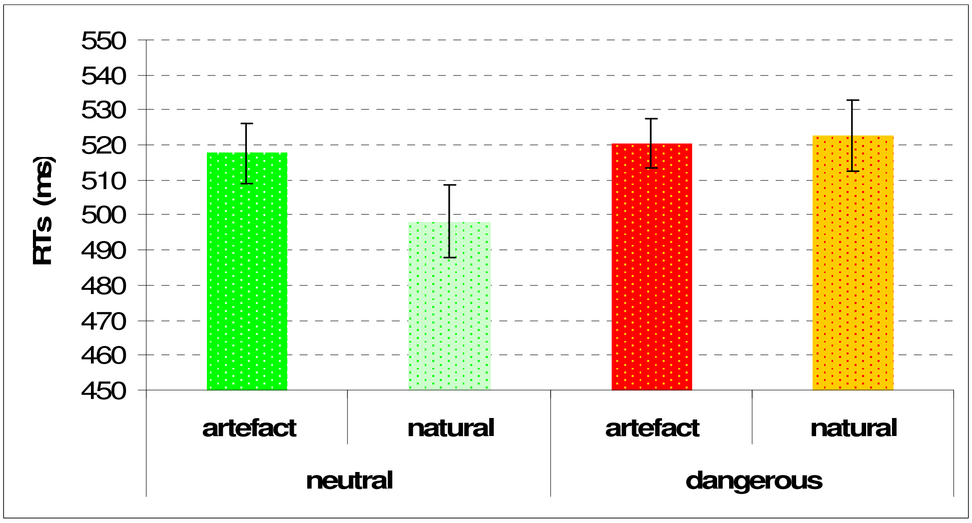


Figure 3.9 Study 1, Experiment 3: *Object Typology* and *Object Category* interaction for RTs (females group), values are in ms and error bars show standard errors of the means.

3.4.3 Discussion

In keeping with what found with children in the previous experiments, adults responded slower to dangerous than to neutral objects, probably due to an interference or a blocking mechanism. Our data do not allow us to disentangle between two alternatives. Indeed, it is possible that even dangerous objects evoke affordances, but responses to them are slowed down due to the presence of a late occurring blocking mechanism. Alternatively, it is possible that dangerous objects, even if they are potentially graspable, do not invite reaching/grasping the object, but that they rather evoke aversive affordances, since their danger is perceived from very early processing phases. Literature on approach-avoidance effects has shown that positively connoted words evoke approach movements, while negative connoted words evoke avoidance movements (e.g., Chen & Bargh, 1999; Van Dantzig, Pecher, & Zwaan, 2008; Freina, Baroni, Borghi, & Nicoletti, 2009). However, in these studies emotional stimuli are referred to the self, while in the present study participants observe hands of others in potential interaction with objects. Previous TMS data have shown that observing pain inhibits hand muscles through the cortical motor system (e.g., Avenanti et al., 2005). However, in our study the effect of the object might be independent from the effect driven by the action observation. To this aim the results by Morrison and colleagues (Morrison, Tipper, Fenton-Adams, & Back, 2012) are relevant, showing with fMRI that inferior postcentral gyrus is activated with dangerous objects, irrespective of whether a grasping or a withdrawal action on the object is observed. Further observations on the mechanisms underlying the possible inhibitory mechanisms will be introduced in the general discussion.

Interestingly, adults are aware also of the distinctions between object categories. Specifically, females responded faster to natural objects than to artefacts, as registered in Experiment 1. As stated before, this result is in line with the literature (Borghi et al., 2007; Vainio et al., 2008; Anelli et al., 2010) and probably depends on the activation of both manipulative and functional information with artefacts, and only of manipulative information with natural objects. This experiment adds to previous results in the literature as it shows that participants responded differently to the two object typologies only when they dealt with neutral objects, while with dangerous objects the perception of their danger overcame more fine-grained categorical distinction. It remains to be explained why females responded differently to natural objects and artefacts, while males did not.

Notice, however, that in males we found evidence of a resonant mechanism, as they responded faster to the man hand prime than to the other primes. Importantly, the fact that they responded faster to the grasping hand of a man proofs their sensitivity to the different motor program conveyed by the hand. This sensitivity to hand posture was not present in children, nor it is present in women. Whereas all were equally responsive to object dangerousness, females responded differently to object categories, while males responded differently to hand postures revealing sensitivity to fine-grained aspects of action. One can speculate that this results pattern has an evolutionary basis. If we consider our ancestors, it is well known that males were primarily hunters, while women had to select plants and vegetables to promote agriculture.

3.5 General Discussion

Results (Anelli et al., in press b; Anelli et al., under review) clearly demonstrate that both children and adults, males and females, are sensitive to the difference between dangerous and neutral objects. Dangerous objects produce an interference, as the slower RTs required to process dangerous compared to neutral objects demonstrate. However, our data do not allow us to disentangle between different accounts, discussed in the previous section. We suppose that only data on time course would allow us to more precisely determine to what the delay with dangerous objects is due and to clearly determine whether affordances or aversive affordances are activated. Nevertheless, some speculations are possible concerning the different underlying neural mechanisms involved during processing of dangerous stimuli compared to neutral ones. Studies on the emotional Stroop effect (e.g., Algom, Chajut, & Lev, 2004) reveal that response times are generally slowed down with emotional stimuli. The slowdown of responses can be associated to an inhibition effect provoked by a selective attention mechanism, as that typically characterizing Stroop effect. Alternatively, it has been proposed that with emotional stimuli a generic slowdown due to the threatening character of the stimuli is present (Algom et al., 2004). This explanation is compatible with our data. However, another possible way to understand the mechanism underlying the slowdown of response times with dangerous stimuli compared to neutral ones is in terms of the mechanisms highlighted by Caligiore and colleagues (Caligiore, Borghi, Parisi, Ellis, Cangelosi, & Baldassarre, 2012) for treating cognitive conflict. Their TRoPICAL model (see also Caligiore et al., 2010) is able to account for negative compatibility effects that emerge when participants have to respond to target-objects avoiding to respond to distractors. The model shows that the dorsal and ventral pathways process information related to both the target-object and the distractor. This model can be used to account for our data as well. Indeed, Caligiore et al. (2012) have shown that the prefrontal cortex (PFC) plays a double role, exerting both an inhibitory and an excitatory control (Knight, Staines, Swickc, & Chaocet, 1999; Munakata, Herd, Chatham, Depue, Banich, & O'Reilly, 2011). In Caligiore et al. (2012), this inhibitory control allows the model to refrain from executing the actions suggested by the distractors; similarly, since PFC can receive inputs from the emotional circuits, in our case it may allow participants to inhibit the tendency to respond to affordances in case of dangerous objects. A further possibility (for example, see Etkin, Egner, Peraza, Kandel, & Hirsch, 2006; Egner, Etkin, Gale, & Hirsch, 2008) is that two different, separable circuits underlie cognitive and emotional conflict: a lateral PFC system devoted to resolving conflict non related to emotional stimuli, and a rostral anterior cingulate system devoted to resolving emotional conflict and associated with a top-down inhibition of the amygdala with emotional distractors. However, as recently argued by Munakata et al. (2011) the PFC would have an impact on inhibition related emotional stimuli as well. Indeed, the authors show that PFC, specialized to abstract goal-derived information, is at the basis of different forms of inhibition: a form of global inhibition involving cortical and subcortical regions, among which those related to fear processing, and a form of indirect competitive inhibition in neocortical and subcortical regions.

As second relevant point, we demonstrate that children are not equally sensitive to the difference between objects categories (natural vs. artefacts), that starts to develop in children but appears clearly only in the adult-female group. This results pattern suggests a specific developmental trajectory. Even if the task requires to distinguish between artefacts and natural objects, at all ages participants respond differently to dangerous and neutral objects, but more fine-grained differences such as those related to object category emerge later.

As third result, the effect of primes reflects the existence of a resonant mechanism, that is already developed in children and which becomes progressively more fine-tuned with age. Indeed, children already resonate more to the human hand than to the non biological primes. The simplicity of the brick leads us to exclude that faster response times were due to lower visual complexity of the human hand prime. Crucially, the human hand prime differed not only from the brick, but also from the robotic hand. This effect can be due to a higher motor resonance when the hand is similar to our own. While a higher resonance with biological than with not biological stimuli is already present in children, they do not respond to gender differences of the hand primes. Results reveal that adults become more sensitive to fine-grained aspects of the biological stimuli. Indeed, male participants respond faster to hands of their own gender, characterized by a specific posture, the grasping one. Why this gender dependent motor resonance and the ability to distinguish between a static and a grasping posture is not present with women can be matter of further investigation. It could depend on the effect of gender stereotyping which leads to respond fast to man’s hand, or on the higher attention women paid to objects characteristics instead than to action characteristics.

The direction of the effects we found (i.e. facilitation with prime stimuli that might produce resonance, interference with dangerous compared to neutral objects) allows us to advance hypotheses concerning the underlying mechanisms. Our results indicate that observing a hand in a given posture induces participants to prepare an action, probably through the mediation of the mirror neuron system. This action is prepared faster when the hand we observe is rather similar to our own. While children rely only on the distinction between biological hands and other stimuli, adults become aware of gender and postural differences in biological hands. The resonant effects we found are in line with the ideomotor theories, in particular with the Theory of Event Coding (TEC; Prinz, 1997; Hommel et al., 2001), according to which perceived events and actions are represented by the same “event codes”, and rely on the same representational code. For this reason, the more similar are the observed action and the performed action, the more motor responses would be facilitated. Once the motor response is prepared, however, it has to be adapted to a specific object. Responses are fast and straightforward when neutral objects are presented. When dangerous objects are displayed, instead, a blocking mechanism seems to intervene, producing longer response times. The absence of an interaction between prime and objects suggests that two different neural systems are involved in an independent and not really integrated fashion: one, possibly mediated by the mirror neurons, triggered by the action observation, the other, possibly mediated by the canonical neurons, triggered by the objects displayed (Rizzolatti & Craighero, 2004). The absence of this integration could be due to the specific paradigm we used, i.e. a priming one. Indeed, in a recent study by Morrison et al. (2012), there is evidence of integration between action and object information. In both an imaging (fMRI) study and a tactile detection experiment, participants observed hands in an approaching/grasping or withdrawing posture toward noxious or neutral objects, and were required to evaluate whether object and action were appropriate to one another. Results showed that distinct sensorimotor regions were activated with specific responses to different stimuli characteristics (i.e., kind of object, kind of action, and action-object interaction). In particular, viewing grasping actions toward dangerous objects activates the postcentral sensorimotor cortex that integrates both object and action information in order to process the sensory outcomes of observed hand-object interaction. Overall, somatosensory cortices and inferior parietal lobule seem to anticipate the consequences of observed hand-object interaction with noxious objects, as the painful grasp condition is more activated compared to all other conditions.

Overall, our study is the first to our knowledge that investigates development of the sensitivity to dangerous and neutral objects, and also of the effects that these different objects can have on other organisms, such as other humans, males and females, and robots. Results of the present study corroborate and widely extend previous ones, showing resonant mechanisms when interacting with dangerous objects. Certainly, further studies are necessary, in order to investigate in deep this complex issue and to better understand the neural mechanisms underlying these behavioral effects.

PART 2

CHAPTER IV

SIMON EFFECT

The second part of the thesis is related to the “Simon” theme. Thus, in this chapter I present this issue both at a theoretical and empirical level. First, I will start from researches on stimulus–response (S–R) compatibility to introduce the first experimental evidence on the classical “Simon effect”. Second, a paragraph will be dedicated to most recent studies on the so-called “social or joint Simon effect”, showing how this effect has been used as a tool to investigate a relevant topic of social cognition, the joint action, and different cognitive processes related to it, such as perception, attention, action planning, and cognitive control. Finally, a section will be focused on the discussion of the reported empirical findings in a broader theoretical perspective on joint action, within which can be placed both the Study 2, presented in the next chapter, and the Study 3, presented in Chapter 6.

4.1 Classical Simon effect

Traditional in cognitive psychology researchers used the stimulus–response (S–R) compatibility to consider the link between systems for perception and action. In a spatial S-R compatibility task a participant was required to make spatial responses (e.g., left and right key-presses) on the basis of the stimulus location (e.g., left or right)). The result is that response times are faster and more accurate when both the stimulus and response locations correspond (i.e., compatible condition) than when they do not correspond (i.e., incompatible condition), (Alluisi & Warm, 1990). Specifically, response times are about 50 ms faster when participant makes a left key-press response to the left stimulus and a right key-press response to the right stimulus than when participant experiences the opposite mapping (e.g., Shaffer, 1965). The spatial compatibility effect is considered as a function of the relative locations of stimulus and response (Nicoletti, Anzola, Luppino, Rizzolatti, & Umiltà, 1982), and it is explained in terms of response selection; namely, response selection is faster when the spatial codes for stimulus and response correspond than when they do not correspond (Proctor & Reeve, 1990).

A similar spatial compatibility effect is registered when a non-spatial feature (e.g., the stimulus colour) is defined as relevant and the stimulus location as irrelevant, and participant is required to respond (with a left or right key-press) to the relevant non-spatial feature (e.g., red or green stimulus), (see Figure 4.1 for a schematic representation of the classical Simon task). Also in this kind of task, responses are faster and more accurate when the irrelevant stimulus location and the correct response location correspond (i.e., corresponding trials) than when they do not correspond (i.e., non-corresponding trials), hence indicating that stimulus location influences performance even if task-irrelevant. This phenomenon is known as “Simon effect” (Simon & Rudell, 1967; Simon, 1990; for reviews, see Lu & Proctor, 1995; Proctor & Vu, 2006; Rubichi, Vu, Nicoletti, & Proctor, 2006).

The seminal study on this effect was conducted by Simon and Rudell (1967), who were originally interested to investigate the hemispheric dominance for speech. To this aim, they programmed an auditory reaction-time task and verified the relation between ear stimulated and handedness. More specifically, this experiment was aimed to demonstrate that right-handed participants would respond faster to a verbal command (e.g., the word “right” or the word “left”) when it was heard by their right ear than by their left ear, while left-handed participants would respond faster to a command when it was heard by their left ear than by their right ear. Even though this predicted result was not registered, Simon and Rudell (1967) obtained another interesting result: reaction times were faster when the "right" command was presented to the right ear than to the left ear, and, vice-versa, reaction times to the "left" command were faster when it was presented to the left ear than to the right ear. Namely, responses were 42-ms faster when the command was heard in the corresponding ear rather than in the non-corresponding ear. In this case, the ear in which a participant heard the command was the task-irrelevant feature that nevertheless influenced the performance. This work showed for the first time the tendency to react to the source of a stimulus. Later, Simon and colleagues demonstrated that the Simon effect emerged not only with auditory stimuli, but also with visual stimuli (Craft & Simon, 1970). Simon explained the effect as follows: "A strong stereotypic tendency to respond initially to the directional component of a stimulus rather than to its symbolic content" (Simon & Rudell, 1967, p. 31).

Contemporary accounts widely assume that the Simon effect is due to a conflict, emerging at the stage of response selection (e.g., Rubichi, Nicoletti, Umiltà, & Zorzi, 2000; Rubichi & Pellicano, 2004). More specifically, according to dual-route models (De Jong, Liang, & Lauber, 1994; Kornblum, 1994), response activation is possible by means of two routes: one is the automatic or direct route and the other is the intentional or indirect route (Hommel & Prinz, 1997). The direct route automatically activates the corresponding response through pre-existing long-term S–R associations, linking a stimulus to its spatially corresponding response; conversely the indirect route activates the response generated on the basis of task instructions through short-term and task-defined S–R associations (e.g., Zorzi & Umiltà, 1995). In corresponding trials, the response location corresponds to that of the stimulus and thus the two responses activated both by direct and indirect route are the same; in this case no conflict arises. Instead, in non-corresponding trials, the response location does not correspond to that of the stimulus and thus the two activated responses do not correspond; in this case the conflict must be resolved before the execution of the correct response, leading to a slowing of response times. The difference between corresponding and non-corresponding trials results in the classical Simon effect.

I will not go into presentation of several experimental evidence produced in these years nor of theoretical developments or controversies (e.g., Hommel, 2011; Proctor, 2011), as beyond the aims of the thesis.

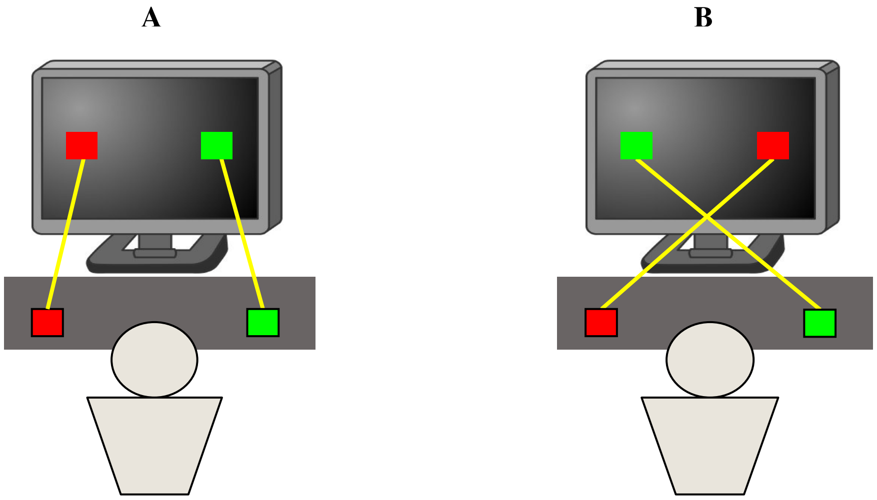


Figure 4.1 Schematic representation of the classical Simon task: participant is seated centrally in front of a monitor, and responds to red stimulus with a left key-press and to green stimulus with a right key-press. Panel A shows compatible conditions, in which stimulus and response locations correspond. Panel B shows incompatible conditions, in which stimulus and response locations does nor correspond.

4.2 Joint Simon effect

More relevant to the purpose of the present work, several recent studies have shown that a similar effect (defined “joint Simon effect”) occurs even when the Simon task is shared between two participants (defined “joint Simon task”, see Figure 4.2 for a schematic representation). As anticipated in Chapter 1 (see section 1.5.2), Sebanz and colleagues (Sebanz et al., 2003) were the first to develop this new paradigm. In their experiment, participants were shown photographs of a centrally presented right hand pointing to the right, to the left, or straight, with the instruction to press one of two lateralized keys (e.g., left and right key-presses) according to the color of a ring on the index finger (e.g., red or green ring). Participants were required to perform the task in three different conditions: in the two-choice condition participant sat centrally in front of a monitor and responded to one ring color with a left key-press and to the other color with a right key-press (e.g., participant responded to green ring with a left key-press and to red ring with a right key-press). In the joint go/no-go condition participant was paired with another participant and they sat side-by-side in front of a monitor, and each participant was required to respond only to one color with a key-press (e.g., participant who sat to the left responded to green ring with a left key-press, while participant sitting to the right responded to red ring with a right key-press). In the individual go/no-go condition participant sat laterally (e.g., to the right side) while an empty chair was beside him/her, and he/she responded to only one color with a key-press (e.g., participant responded to red ring with a right key-press). Response times were faster when the responses spatially corresponded to the pointing direction of the hand (corresponding trials) compared to when they did not correspond (non-corresponding trials). This advantage for corresponding trials was evident not only when participant performed the task alone (two-choice condition), responding to both colors (classical Simon effect), but also when he/she performed the task with another participant (joint go/no-go condition), each responding to only one color (joint Simon effect). In contrast, the effect was absent when participant performed the task alone but responding only to one color (individual go/no-go condition). Sebanz and colleagues explained the emergence in the joint go/no-go condition of a similar effect to that registered in the two-choice condition as follows: "Given that the action alternative at the other's disposal is represented, the spatial dimension of the two responses is also represented and thus overlaps with the irrelevant spatial dimension of the stimulus. Hence, just as in a normal Simon task, the response corresponding to the spatial information provided by the stimulus is automatically activated” (Sebanz et al., 2003, p. 18).

This finding suggests that when co-acting with another person, participants consider the other person’s actions and consequently activate relative response codes in their action plans. According to Sebanz et al. (2003), the joint Simon effect shows that each participant represented the stimulus-response rules and the action plans of both individuals (also defined agents or actors) involved in the task: in other words, they created shared representation or co-representation. The process behind the spatial-compatibility effects was activated by the interaction between the response codes activated through observation and the internal response codes. In the individual go/no-go task this effect was absent because only one response code was formed and thus no conflict between spatial codes occurred. It can be argued that people may represent stimulus events independently from their target and may represent an action without considering who is carrying it out.

The same effect reported by Sebanz et al. (2003) occurs even with symbolic stimuli that do not convey spatial information. In the study of Atmaca, Sebanz, Prinz, and Knoblich (2008), participants were required to respond with a left or right key-press to odd and even numbers, ranged from 2 to 9. Results showed that, when a participant performed this task alone, responses were faster with a left key-press to small numbers and with a right key-press to large numbers. This effect of number magnitude (irrelevant to the task) is the so-called “SNARC effect”, due to an automatic magnitude representation on a mental number line, from the left to the right, activated by the perception of numbers (Dehaene, 1997). More interesting, when two participants sat side-by-side and performed the task together (e.g., one responded to even numbers and the other to odd numbers) the same effect was registered. Namely, participant sitting on the left side was faster to respond to small numbers, while participant sitting on the right was faster to respond to larger numbers. This result indicates that, as in the original study of Sebanz et al. (2003), participants represented their own action alternative in relation to the co-actor's actions.

Many questions are raised from these early data on shared task representations: in the following I will try to present some relevant issues and how researchers addressed them.

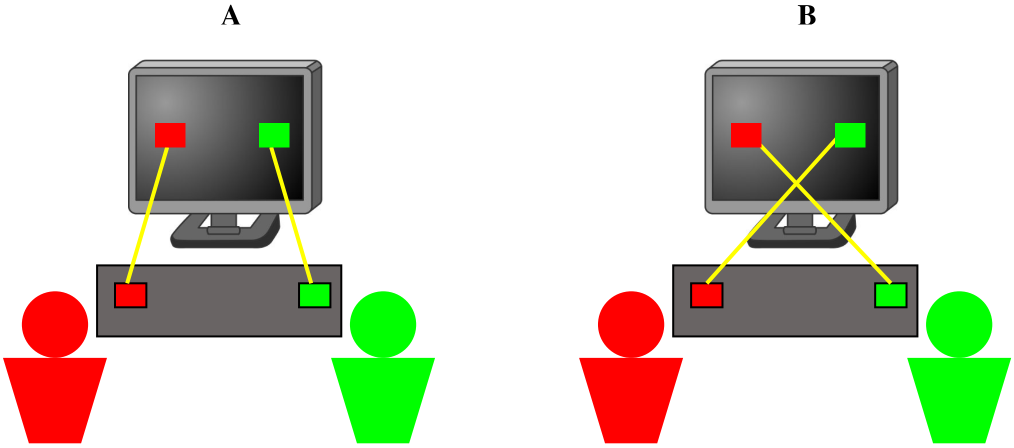


Figure 4.2 Schematic representation of the joint Simon task: participants are seated side-by-side in front of a monitor. Each participant was required to respond only to one color with a key-press: participant seated to the left responds to red stimulus with a left key-press; participant seated to the right responds to green stimulus with a right key-press. Panel A shows compatible conditions, in which stimulus and response locations correspond. Panel B shows incompatible conditions, in which stimulus and response locations does nor correspond.

4.2.1 Cognitive mechanisms

One interesting and debated point concerns the cognitive mechanisms underlying the co-representation effect. Since the first evidence showed that this effect occurred in complementary tasks (i.e., tasks that gave the participants the impression of being performing in collaboration with another person), Guagnano, Rusconi, and Umiltà (2010) assessed whether the same effect emerged even when two participants are completely independent. To this aim, the two participants performed two independent detection tasks (i.e., one responded to red stimuli and the other to blue stimuli) and, in order to avoid the idea of complementarity and turn-taking, on 80% of the trials, the stimuli required a response from both participants. The joint Simon effect emerged when the two participants sat close to each other within arm's reach (in the so-called peripersonal space) and performed a task in which they did not collaborate. However, the effect was absent when participants performed the social task outside of each other's arm-reach (i.e., outside peripersonal space). Guagnano et al. (2010) explained this finding suggesting that, when participants are next to each other, the co-actor represents a spatial reference point for coding one's own action in space. Thus, they claimed that the joint Simon effect does not necessarily imply a representation of the other's action.

A similar compatibility effect was registered in the study of Welsh (2009), when participants sat close to each other and performed the task with their hands crossed or uncrossed. This result shows that the spatial coding can be based on the position of one's body relative to the other's body, or on the position of one's hand relative to the other's hand.

Still regarding the cognitive mechanisms subserving shared task representations, some studies indicate that for others' actions to be included in one's own action plan, they must be of a biological nature (Tsai & Brass, 2007). More specifically, in their study Tsai and Brass (2007) investigated whether co-representation occurs only when participants interacted with a biological agent or whether co-representation can also emerge when individuals perform the task with a non-biological agent. Participants experienced a joint Simon task, responding to targets (red or green) with a key-press, while a videotaped hand (wooden or human) responded to the target of the other color. Results showed that the joint Simon effect is not limited to real-world interactions, as reported by previous studies, since it emerges also when participants act with a computer human hand, rather than with another real participant. Moreover, this effect occurs only when participants perform the task with conspecifics (i.e, when they watch responses of human hand) and not with a non-biological agent (i.e, when they watch responses of wooden hand). Namely, the joint Simon effect is biologically tuned.

Other studies have focused on the importance of others' actions visibility (Sebanz et al, 2003; Sebanz, Knoblich, & Prinz, 2005a; Welsh, Higgins, Ray, & Weeks, 2007; Tsai, Kuo, Hung, & Tzeng, 2008). For example, Tsai et al. (2008) investigated the nature of co-representation and how knowledge about another's intentional behavior influences participant's performance. They manipulated the identity of the co-actor in a joint Simon task, using either a real third-person or a computer program. Each participant performed the task under the implemented belief that he/she was interacting with another, thus there was not the influence of actor presence. In one condition participants were informed that they were performing the task (e.g., responding to green stimuli) with a person in another room (e.g., responding to red stimuli), thus a biological agent, while in the other condition with a computer program (e.g., responding to red stimuli), thus a non-biological agent. However, in both conditions the responses of the co-actor were random sequences generated by the same computer program and participants did not receive any visual-auditory feedback on the performance of the other agent. In line with their previous study (Tsai & Brass, 2007), Tsai et al. (2008) found a joint Simon effect only when participants believed that they were performing the task with a biological agent, while the effect was not present when they believed that they were performing the task with a non-biological agent. Notice that this biologically tuned effect emerged even in the absence of any kind of feedback, thus suggesting that shared representation occurs on the basis of the believed animation of the co-actor.

4.2.2 Neural mechanisms

Besides the study of cognitive mechanisms underlying shared task representations, some electrophysiological studies have been conducted to explore the neural mechanisms.

For example, some researchers investigated how performing a task with another person affects action planning and control (Sebanz, Knoblich, Prinz, & Wascher, 2006b; Tsai, Kuo, Jing, Hung, & Tzeng, 2006). Through event-related potential (ERP) measurements, these studies can extend previous reaction time (RT) findings. In fact, recording electrophysiological responses to stimuli referring to other's action, it is possible to investigate the source of action selection conflicts and action control processes. In the study of Sebanz et al. (2006b), ERPs were measured while participant performed a Simon task alone (individual condition) and with another agent (group condition). The results showed that acting together requires a particular involvement of processes related to action planning and control, due to the creation of other's action representation. In particular, the amplitude of the Go P3 component indicates that action-relevant stimuli which refer to the other's action cause a response similar to that referring to one's own action. Moreover, the amplitude of the No-Go P3 component shows that participant anticipates the other's action and has a sort of tendency to act that, however, must be suppressed. Thus, exists an inhibitory mechanism that suppresses action tendencies during the perception of stimuli requiring another's action. These findings support the claim that both one's own and others' actions are represented in a common representational domain, and that one's own action representation is activated by observing or anticipating other's action.

Similarly, Tsai et al. (2006) conducted a research in which both reaction times (RTs) and ERPs were registered in a Go/No-Go task. In line with Sebanz et al. (2006b), the emergence of the effect in the joint condition indicated that both action perception and action execution share a common coding at the representation level. In addition, they replicated the effect on No-Go P3 component, thus underlying the importance of action anticipation and its crucial role in joint action. Finally, Tsai et al. (2006) revealed that, when a conflict emerged between responses for relevant and irrelevant stimulus dimensions, subjects inhibit responses for irrelevant dimension and select responses for relevant one. Thus, they support the claim that interference effect occurs after the stage of identification of stimulus relevance and, thus, at the stage of response selection (Sebanz et al., 2003).

These researches (Sebanz et al, 2006b; Tsai et al., 2006) can be considered as first examples of how it is possible to study real-time dyadic interactions with neuroscientific methods.

4.2.3 Social modulations

An interesting line of research is being developed recently, focusing on how social variables influence the creation of shared representations. For example, factors such as the characteristics of the co-actors and the kind of the interaction context have been investigated to understand how they can modulate the tendency to take each other's actions into account.

Sebanz, Knoblich, Stumpf, and Prinz (2005b) focused on a possible link between shared task representations and impairments in mental state attribution. They measured and compared the performance on Simon task of individuals with autism and the performance of a control group of healthy participants. Results showed similar co-representation effects on the two groups, thus indicating that autistic deficits in understanding mental states do not influence the creation of representation about the rules specifying the task of another agent.

More relevant to my thesis work and, in particular, to the studies that I will present in the next chapters, other researches investigated the influence of interpersonal relations in task co-representation. Hommel, Colzato, and van den Wildenberg (2009) tried to understand the role of the valence of the interaction between two co-acting individuals. A joint Simon task was used in two conditions: in the first condition participant performed the task with a confederate (i.e., an accomplice of the experimenter) who was friendly and cooperative, namely participants were involved in a positive relationship; in the second condition participant acted with a confederate intimidating and competitive, namely participants were involved in a negative relationship. Results showed that the Simon effect was restricted to the positive relationship, whereas the negative relationship leaded to a reduction of the effect. Thus, this finding suggests that shared task representations only occur in positive relationships and, against the assumption that task representations are socially shared (e.g., Sebanz et al., 2003), it is on favour of a separate representation of self-generated and other-generated actions. Hommel et al. (2009) proposed that positive relationships strengthen the link between attributes and actions related to oneself and actions related to the other (Aron, Aron, Tudor, & Nelson, 1991), thus favouring the integration between self- and other-generated actions in a common representation. On the contrary, negative relationship may increase the self-other distinction, thus preventing this integration. From this view, it derives that the emergence of shared representations strictly depends on the strength of the psychological connection between co-acting individuals: stronger is this connectedness, more likely is that self and other actions are integrated in a common representation.

Similarly, Kuhbandner, Pekrum, and Maier (2010) investigated the influence of mood state. To induce an affective state, participants watched a neutral, positive, or negative film clip before to perform the joint Simon task. Results demonstrated a larger joint Simon effect when the task was performed after the induction of a positive mood, revealing that positive affect enhanced the activation of the response code actually associated with the other’s action. Instead, no effect was observed after the induction of a negative mood, indicating that motor representations associated with the other’s action were no longer activated.

Along this line, Ruys and Aarts (2010) considered the role of interdependence between participants on the emergence of shared representations. In their experiment an auditory version of the joint Simon task was employed and participants believed that they were interacting with another person placed in another room. The joint Simon effect was measured in three experimental conditions: in the independent condition a reward was given to the ten best-performing participants (i.e., the achievement of a personal goal was independent of the co-actor), in the cooperative condition both participants of the five best performing couples earned a reward and in the competitive condition ten winners were randomly selected for the reward (i.e., in these two last conditions the achievement of a personal goal depended on the co-actor). Results showed that a joint Simon effect emerged under all conditions; however the effect was smaller in the independent condition compared to the other two conditions. To explain their finding, Ruys and Aarts (2010) suggested that both in the cooperative and competitive condition the participants' performance was interdependent and thus they needed to attend to the intentions of the other to successfully complete the task. According to their view, the emergence of shared representations does not depend on whether the participants need to cooperate or compete, rather it depends on whether they attend to the intentions of the other.

4.2.4 Learning

A final point on shared task representations that may be interesting to introduce, and that will be relevant for the Study 3 (Chapter 6), concerns the learning. In fact, recent studies have focused on whether and how jointly practiced task can influence performance on another subsequent joint task (Milanese et al., 2010; Milanese, Iani, Sebanz, & Rubichi, 2011). Studies of individual performance demonstrated that it was possible to modulate performance on the Simon task (i.e., transfer task) by asking participants to perform before (i.e., practice task) a spatial compatibility task with incompatible mapping (Proctor & Lu, 1999). More specifically, whether participants performed a practice task responding to stimuli on the left with a right key-press and to stimuli on the right with a left key-press, they showed a reduced or even a reversed spatial compatibility effect in a subsequent transfer task where they had to respond to color, ignoring the spatial position of the stimuli. This effect is defined as “transfer of learning effect”.

Milanese and colleagues (2010) created a “social” version of this paradigm (i.e., a joint transfer-of-learning paradigm), showing the influence of joint task performance on implicit learning and the transfer of this learning to subsequent performance. Results demonstrated that transfer effects occurred not only when participants performed both the practice and the transfer task together, but also when participants first performed the practice alone and then the joint compatibility task. Instead, the effect was not present when participants first performed the practice together and then performed the compatibility task alone. This finding indicates that the representations in joint task performance are different from the representations in individual performance. The transfer effect occurs from the joint to the joint condition and from the individual to the joint condition, and not vice-versa from the joint to the individual condition.

In another research, Milanese et al. (2011) used the joint transfer-of-learning paradigm to investigate which elements of the practice task are necessary and need to remain constant for this joint transfer-of-learning effect to emerge. Results showed that keeping the same position during both practice and transfer tasks are necessary for the emergence of the joint transfer-of-learning; on the contrary, co-actor identity is not a crucial element. Thus, these findings highlight that the joint transfer-of-learning effect is influenced by spatial parameters of the practice and transfer tasks, but is not tuned to a specific co-agent.

These studies indicate that transfer studies can be a useful new paradigm to study the nature of shared task representations.

4.3 Joint Simon effect and joint action

In this last section I will try to discuss the above reported empirical findings in a wider theoretical perspective on joint action. As I have already revealed in Chapter 1 (see section 1.5.2), joint actions can be considered one of the most important topic in the new trend of cognitive sciences. Indeed, several researches were carried out on this issue, assuming that relevant social constraints for the architecture of individual cognitive processing can be provided by basic forms of interaction. 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 et al., 2006a, p. 70). As we shall see in this section, the coordination required to achieve a common goal includes a combination of perceptions, action plans, and intentions of the individuals involved in the interaction.

Understanding and explaining joint action have first interested philosophers (Tuomela & Miller, 1988; Searle, 1990; Bratman, 2009). They argued that shared intentions are the foundation of joint actions: in fact, compared to individual actions, joint actions involve a shared intention, an essential element for understanding coordination in joint action. Some philosophers claim that shared intentions differ from individual intentions as regards the attitude involved (Searle, 1990; Kutz, 2000), their plural subjects (Gilbert, 1992), or in the way they arise (e.g., by means of team reasoning; Gold & Sugden, 2007). Instead, Bratman (2009) holds that multiple individual intentions constitute shared intentions. Recently, joint action has also become a topic of interest in linguistics that emphasized the role of language (Clark, 1996).

More relevant for the project, psychological researches on perception, action, and cognitive control investigated the perceptual, motor, and cognitive mechanisms underlying processes which are relevant for joint actions, such as planning and coordination. According to what presented in the previous section, cognitive psychologists demonstrated that, at least in part, successful joint actions depend on the ability to share representations (Knoblich & Sebanz, 2006). Shared perceptual representations may arise when individuals direct their attention to where an interaction partner is attending in order to attend to the same objects or events in the environment (joint attention). Shared action and task representations may allow individuals to predict others' actions and integrate others' actions in their own action planning. This task sharing indicates that, while performing a task together, co-actors know what the other's task is and the conditions under which the other will perform a certain action. Namely, the two co-actors involved in a joint action create a shared representation of both their own and other's tasks, and their coordination in real time is supported by the ability to predict each other's actions (Sebanz et al., 2006a).

On the whole, philosophical, linguistic, and psychological approaches have suggested that the capacity to jointly act together is based on the specific ability to share mental states between the participants. Below I shall continue to focus on the psychological approach to this topic and to recent attempts to explain what kind of representations and processes make joint action possible.

As already mentioned, joint actions differ from individual actions in several ways: for example, when individuals perform actions together they had to predict what others are going to do, to control one's behaviour, and to obtain temporal coordination.

4.3.1 Mechanisms and minimal architecture of joint action

Several mechanisms are involved in joint action (Sebanz et al., 2006a). First, joint attention provides a mechanism that allow individuals to share the same perceptual input and direct attention to the same events in the environment. Second, a strong link between perception and action allows individuals to form representations of others' action goals and to predict action outcomes. Third, the prediction of actions based on certain events in the environment and independently by action observation is achieved by forming shared task representations. Fourth, the integration of the "what" and "when" of others' actions in one's own action planning allows action coordination. Finally, in joint actions the combined outcome of one's own and others' actions is more relevant than the results of individual actions.

According to Vesper, Butterfill, Knoblich, and Sebanz (2010), I would present an interesting model or "minimal architecture" that support joint action. Such minimal architecture includes representations, processes, and "coordination smoothers". The first element, representations, is present both in the case of individual and joint action, since individuals had in any case to represent their goals and the tasks necessary to obtain their goals. However, in joint situation individual knows that carry out his/her task is not enough to achieve the goal and that therefore the intervention of another agent become necessary. In this new condition, the agent should represent not only his/her own task, but also the task of the other agent, on the basis of what co-agent is expected to do (i.e., the kind of action the other will perform and the intention that drives that action). This element can be defined the "what" aspect of joint action (Sebanz et al, 2006a). However, in minimal case, the agent might represent only his/her own task, as demonstrated for example by studies on chimpanzees (Melis, Hare, & Tomasello, 2006) and on earliest joint actions between infants and adults (Moll & Tomasello, 2007). Even if this is possible, generally it is useful to represent the other's task, since this allows to make a prediction about what the other will do. In fact, several studies on co-representation discussed in the previous section (e.g., Sebanz et al., 2003, 2005a; Tsai et al., 2006; Atmaca, et al., 2008) showed that individuals represent the other person's task, even when acting on a goal that the co-actor cannot contribute to. In addiction, electrophysiological findings demonstrated that agents mentally execute the co-actor's task (e.g., Sebanz et al., 2006b; Tsai et al., 2008).

As regards the second element of minimal architecture for joint action, Vesper et al. (2010) claimed that two processes are active on the representations: monitoring and prediction. Monitoring processes are useful to establish to what degree a given task and thus a given goal have been achieved, and whether actions are being carried out properly (Botvinick, Braver, Barch, Carter, & Cohen, 2001). Three elements had to be monitored to accomplish a given task and goal: the agent's own task, the co-agent' task, and the goal. In some cases it is sufficient only to monitor the results of the joint action, while in other cases the agents can monitor the other's actions or the results of the other's actor. This last kind of monitoring can improve performance and thus outcomes.

Prediction is the second kind of process activated on the representations, and it takes care of how the actions will be developed and it is also useful for coordination. Some theories which I have already mentioned (the common coding theory, Prinz, 1997; the motor simulation theory, Jeannerod, 1997, 2006; and the motor resonance theory, Rizzolatti & Craighero, 2004) converge on the idea that action observation can support the understanding of goals and intentions. However, as Sebanz et al. (2006a) also remark, to interact successfully with others, knowing what they are currently doing may not be sufficient. As claimed by Pacherie (2012), agents must not only predict the consequences of their own actions (self-predictions), but they must also do the same for the actions of their co-agents (other-predictions), and finally integrate both self and other-predictions to create predictions about the joint consequences of their combined actions (joint predictions). These three kinds or levels of predictions are possible and facilitated through motor simulation which allows to understand how actions will influence the environment and their consequences (Wolpert & Ghahramani, 2000), and to predict our own and others' actions (Wolpert et al., 2003). Predictions can concern expectations about both long-term events and actions online. Researches on motor experience and motor expertise supported the claim that motor simulation plays an essential role in the ability to anticipate others' actions (e.g., Calvo-Merino et al., 2005; Aglioti et al., 2008; for a more detailed discussion on this topic, see section 2.4). This anticipation process allows actors to predict the timing and the future events produced by oneself and others, rather than simply responding, and also to incorporate the timing of others' actions in their own action planning. Consequently, it also improves interpersonal temporal coordination (Keller, Knoblich, & Repp, 2007) that represents the "when" aspect of joint action, crucial for acting synchronously or in turns (Sebanz et al, 2006a).

The third element of minimal architecture for joint action are the so-called coordination smoothers. Despite the presence of a motor simulation mechanism, it can be very difficult to obtain the precise coordination in time or space required by joint action and to predict accurately the others' actions. In these cases, the coordination smoothers may be useful. They represent something aimed to simplify coordination, a kind of "strategic tools". A first type of coordination smoother for agents is to modify their own behaviour so that others can more easily predict future actions (Vesper, van der Wel, Knoblich, & Sebanz, 2011). A second type includes various modes of delimiting and structuring one's own task to reduce the need for coordination (Brennan, Chen, Dickinson, Neider, & Zelinsky, 2008). Further types of coordination smoother are coordination signals (Clark, 1996) and synchronisation (Wilson & Wilson, 2005).

4.3.2 Classification of joint action

After trying to understand which are the elements that seem to underlie the emergence of joint action, now I would propose a kind of classification of such actions that will allow us to read and interpret in a different way many of the concepts already emerged so far. We have just seen that coordination is a key element on joint action. On the basis of several findings presented in the previous section and of some issue discussed in Chapter 1, and according to Knoblich et al. (2011), it is possible to identify two types of coordination during joint action: planned coordination and emergent coordination. "In planned coordination, agents' behavior is driven by representations that specify the desired outcomes of joint action and the agent's own part in achieving these outcomes. In emergent coordination, coordinated behavior occurs due to perception–action couplings that make multiple individuals act in similar ways; it is independent of any joint plans or common knowledge" (Knoblich et al., 2011, p. 62).

As highlighted by definition, emergent coordination can occur not only during planned joint actions, but also between individuals who have no planned to perform actions together, thus it can also occur spontaneously. For instance, I previously (see section 1.5.1) talked about mimicry (Chartrand & Bargh, 1999) that we can now consider as an example of emergent coordination. Three processes of emergent coordination can be identified: entrainment, perception–action matching, and action simulation As anticipated, I have discussed these mechanisms in Chapter 1, thus in the following I would resume them briefly to figure out how they are related to joint action.

Entrainment can be defined as a process that occurs in a direct interaction between co-agents and allow their temporal coordination and synchronization, without a direct coupling (Schmidt, Fitzpatrick, Caron, & Mergeche, 2011).

A second source of emergent coordination is the matching between observed actions and observer's own repertoire of actions. This mechanism can allow mimicry since, when we observe an action, there is an activation of corresponding representations. Both ideomotor theory of action control (e.g., Prinz, 1997; Jeannerod, 1999; Hommel et al., 2001) and findings concerning mirror neurons (for a review, see Rizzolatti & Craighero, 2004) have explained these common representations in perception and action, based on the similarity in actor–object relations. Moreover, this link can also be based on ability and expertise of the observer (e.g., Calvo-Merino et al., 2005). Thus, the perception–action match can favour emergent coordination inducing the same action tendencies in different agents who observe another's actions (Knoblich & Sebanz, 2008).

The third process of emergent coordination, the action simulation, is closely related to the perception-action matching. Indeed, after the emergence of a link between observed and performed actions, observers can apply their internal models to predict the timing and results of observed actions in real time, a process known as action simulation (e.g., Gallese & Goldman, 1998; Gallese et al., 2004). Thus, action simulation can facilitate emergent coordination since it causes the same expectations about the actions in different actors, leading to similar future actions (Knoblich & Sebanz, 2008). Even if emergent coordination can facilitates joint actions, it cannot be fully understood in isolation from planned coordination (Knoblich et al., 2011).

Whereas in emergent coordination the planning can be absent, in planned coordination the co-agents plan their own actions in relation to joint action results or others' actions, thus it can not occurs spontaneously. As already stated in the minimal architecture for joint action, in planned coordination agent knows that the intervention of another agent is necessary to achieve a goal. Two principal processes of planned coordination can be identified: shared task representations and joint perceptions.

In shared task representation process, since agents know that they are not going to achieve alone their goals, they can consider others' motives, thoughts, or perspectives and, moreover, they can make predictions about the consequences of their own actions, about the consequences of the actions of their co-agents, and about the joint consequences of their combined actions (Vesper et al., 2010; Pacherie, 2012). Shared task representations provide control structures that allow agents to flexibly engage in joint action, specifying the individual parts each agent had to execute and thus in turn favouring monitoring and prediction processes that allow interpersonal coordination in real time (Knoblich & Jordan, 2002; Pacherie & Dokic, 2006). More and more psychological experiments were carried out to investigate how individual performance is modulated by co-actors' tasks. Several data showed that agents form very specific task representations, which included both their own part of the task and the part to be performed by the co-actor (e.g., Sebanz et al., 2003) Namely, actors form shared representations of tasks quasi-automatically, even if representing the co-actor's task is not necessary to execute their own part or even when it would be more effective to ignore one another. In fact, behavioral and electrophysiological findings reviewed in the previous section support this claim. Whether agents represent others' tasks does not appear to depend on whether doing so is necessary for performing their own tasks effectively, nor always on directly perceiving their co-actors. Rather it does depend on believing that the other task is being performed by a human agent rather than a non-human one (Tsai & Brass, 2007), and it depends on whether agents are acting in each other's peripersonal space (Guagnano et al., 2010). Representing a co-actor's task leads to inhibit oneself from performing others' actions and to have one's motor system sensitive to others' errors (Sebanz et al., 2006b; Tsai et al., 2006). These findings show that shared task representations influence how agents monitor and plan their actions, thus highlighting how shared task representations could facilitate joint action. By means of these representations, agents monitor and plan both sets of actions and thus they can coordinate their actions and predict their joint results. Overall, shared representations have been shown to emerge even when the task would in principle allow participants to act without considering and representing the other’s action, hence suggesting that they are automatically created any time individuals act in a social context. However, the automatic nature of such shared representations has been put into question by the results of recent studies suggesting that social and emotional factors may modulate their emergence (Hommel et al., 2009; Kuhbandner et al., 2010; Ruys & Aarts, 2010).

As regards the second process of planned coordination, namely joint perception, including another’s perceptions into one’s own representation of the other’s task can improve planned coordination. For example, this kind of process is involved when co-actors’ perspectives on a jointly perceived environment are different. Moreover, when perceptual access to objects in the environment differs between co-actors, joint perception process consists in make inferences about what a co-actor can or cannot perceive (e.g., Brennan & Hanna, 2009). Thus, joint perceptions could help to create a common ground between co-actors, to adapt one’s own task, and to facilitate monitoring of the other’s task.

To briefly summarize, in the second part of this section I reported a distinction between two types of coordination, each supports joint action. On the one hand, emergent coordination occurs spontaneously and involves individuals who have no planned to act together, and it is supported by entrainment, common perception–action matching, and simulation processes. On the other hand, in planned coordination individuals plan their own actions in relation to joint action goal or in relation to others’ actions, and it relies on shared task representations and joint perceptions. Most forms of joint action require both emergent and planned coordination because they are two complementary processes whose synergy allows successful joint action (Knoblich et al., 2011). In fact, planning alone does not allow agents to synchronize or to predict others’ future actions based on their own action repertoire, features of joint action enabled by emergent coordination. Conversely, emergent coordination alone does not allow agents to distribute different parts of a task among themselves or to adjust their actions to others, features of joint action enabled by planned coordination.

Certainly, future researches on joint action should further investigate how emergent coordination and planned coordination are involved together, and how agents are able to integrate the more basic processes of emergent and planned coordination with the higher-level representations and processes postulated in theory of mind research, such as mental state attribution. Some of the studies reviewed above indicate the possibility that emotional factors, what agents believe, and their social relations can strongly influence the processes underlying joint actions. In fact, in the next chapters I shall present two studies aimed at investigating the influence of the co-agents' group membership on the emergence of joint action and, in particular, on the emergence of shared representation.

CHAPTER V

STUDY 2:

GROUP MEMBERSHIP AND JOINT ACTION

5.1 Introduction

The need to investigate cognition and action in a social context has become more and more evident in recent years, and several research efforts are focusing on studying joint action, that is, the ability to coordinate our actions with those of others (Sebanz et al., 2006a). As studies reviewed in the previous chapter suggest, this ability may depend on the creation of shared representations that integrate in the same action plan current and predicted self and other's actions (e.g., Knoblich et al., 2011; Rubichi et al., 2011).

As has been extensively explained in Chapter 4, a task recently used to investigate joint action and the emergence of shared representation is the Simon task (Sebanz et al., 2003). Briefly resuming, in the classical Simon task, participants respond to a non-spatial feature (e.g., color) of stimuli presented left or right of fixation point with assigned right and left key-presses. The Simon effect refers to the finding that performance is faster and more accurate when stimulus and response location correspond compared to when they do not (Simon & Rudell, 1967; for reviews, see Proctor & Vu, 2006; Rubichi et al., 2006), hence indicating that stimulus location affects performance even if task-irrelevant. It is widely assumed that the effect is due to a conflict, emerging at the stage of response selection (e.g., Rubichi et al., 2000; Rubichi & Pellicano, 2004), between two alternative response codes, one generated on the basis of task instructions and the other automatically activated through preexisting associations linking a stimulus to its spatially corresponding response (e.g., De Jong et al., 1994).

More relevant to the purpose of the present work, several recent studies showed that a similar Simon effect occurs even when the Simon task is shared between two participants (e.g., Sebanz et al., 2003, 2005a; Milanese et al., 2010; Ferraro, Iani, Mariani, Milanese, & Rubichi, 2011). The occurrence of the joint Simon effect suggests that each participant automatically represented the other's part of the task and integrated this representation in his/her action planning. Indeed, in the absence of such a shared representation, the effect would not have been evident due to the lack of a competition between two alternative responses. (Knoblich et al., 2011; Rubichi et al., 2011).

Several findings reviewed in Chapter 4 demonstrate the automatic nature of shared representations, that seem to emerge any time individuals act in a social context. However, recent studies suggest that social and emotional factors may modulate the emergence of such shared representations. Briefly resuming some results previously discussed and relevant for the present study, the joint Simon effect seems to be modulated by the valence of the interaction between two co-acting individuals, since it emerged only when participants were involved in positive relationship, whereas negative relationship leaded to a reduction of the effect (Hommel et al., 2009). In the same way, a larger joint Simon effect is registered when a positive mood was inducted between participants, while no effect is observed after the induction of a negative mood (Kuhbandner et al., 2010). Similarly, a larger joint Simon effect emerges when performance of two co-actors is interdependent, both during cooperative and competitive conditions, compared to when performance is independent (Ruys & Aarts, 2010). Overall, these data put into question the automatic nature of shared representation.

Looking at social psychology studies, they indicate that the process of social categorization, that is the perception of belonging to a social group, can influence thinking, feeling, and behaving toward members of the ingroup (i.e., the group the individual is a member of) versus members of the outgroup (i.e., the other group). For instance, social categorization enhances perception of differences between groups and of similarities within the group (Allen & Wilder, 1975, 1979; Doise, Deschamps, & Meyer, 1978). More relevant for the present study, there are indications that when individuals categorize themselves as group members, the group to which they belong becomes included in the self (Smith & Henry, 1996).

The aim of the present study (Iani et al., 2011; Anelli et al., in press a) was to assess whether shared representations, as indexed by the presence of the joint Simon effect, are modulated by group membership. Stated differently, we hypothesized that the joint Simon effect should emerge when co-acting individuals perceive themselves as part of the same social group. On the contrary, it was expected to disappear when co-actors perceive themselves as belonging to different social groups.

The available literature suggests that identification with a group may occur at different degrees. According to some authors, awareness of belonging to a common category is the necessary and sufficient condition for group formation. Crucially, the manipulation of minimal cues is often sufficient to motivate identification with a group (Tajfel et al., 1971; Billig & Tajfel, 1973; Tajfel & Billig, 1974). In these works, the differentiation between ingroup and outgroup occurred even when allocation into groups was arbitrary and virtually meaningless. Other authors posit that individuals perceive themselves as part of the same group if they are aware of belonging to a category, share a common goal, and perceive themselves as positively interdependent with respect to goals and means to attain these goals (Rabbie & Horwitz, 1969).

Based on these considerations, we ran two experiments in which individuals were required to perform a Simon task along another person who was perceived as belonging either to the same group or to a different group and manipulated group formation. In Experiment 4, participants were divided arbitrarily into two groups, based on a trivial and almost completely irrelevant basis, and they were then asked to perform a Simon task with an individual who was supposed to belong to the same group or to a different group. In Experiment 5, we manipulated whether the goals of two jointly acting individuals were positively related and hence the success of one individual made the success of the other more likely, or whether they were negatively related and hence the success of one member rendered the success of the other less likely. In both experiments, the joint Simon effect was expected to show up when participants perceived themselves as ingroup members and to be absent when they perceived the other as an outgroup member.

5.2 Experiment 4

The present experiment aimed at investigating whether the differentiation between ingroup and outgroup obtained by manipulating minimal cues (e.g., Tajfel et al., 1971) is effective in modulating the arising of the joint Simon effect. This would suggest that the activation of shared representations is sensitive to minimal ingroup–outgroup distinctions.

Based on the performance on two cognitive tasks, participants were ostensibly placed in either the "synesthetic" or the "differentiator" group depending on their "cognitive style" (Cadinu & Rothbart, 1996). In reality, performance on the two tests was not scored and participants were arbitrarily divided. After being categorized, participants performed a joint Simon task along with an individual who was believed to belong either to the same group or to a different group.

If perceiving oneself as part of a group decreases the distinction between self and others belonging to the same group, and increases the distinction between self and others belonging to a different group, a joint Simon effect should be evident when coupled individuals are categorized as belonging to the same group, while it should be absent when they are categorized as belonging to two different groups.

5.2.1 Methods

5.2.1.1 Participants

Thirty-two undergraduates students from the University of Bologna (10 males and 22 females) with a mean age of 22 years (age range: 19–31 years) took part in the experiment for monetary reward (5 €). All were right-handed and reported normal or corrected-to-normal vision. All were naive as to the purpose of the experiment and gave written informed consent. Once recruited, they were randomly paired and each couple was randomly assigned to one of two experimental conditions.

5.2.1.2 Apparatus and stimuli

In the first part of the experiment, participants performed two cognitive tasks taken from Cadinu and Rothbart (1996, Experiment 4). For the first task (see Appendix C), participants were presented with a sheet showing a list of 15 nouns (five animals, five trees, and five tools) for 30 s. and, at the end of the time interval, they were asked to write down within 30 s. as many of the nouns of the list as they could recall. For the second task (see Appendix D), participants were presented with a sheet containing a pattern of seven large letters (one A, one C, two Ds, two Es, one F), each of them made of small letters (for example, a big A could be made of small Ds) for 15 s., and were then required to report within 10 s. how many times they saw the big E and how many time they saw a letter composed of small Es.

During the experiment, participants sat side-by-side in front of a 17-inch colour monitor (the eye-to-screen distance was approximately 60 cm). E-Prime 2.0 software was used for presenting stimuli and collecting responses.

Stimuli in the joint Simon task were red or green solid squares (2 x 2 cm), presented 4.5 cm to the left or to the right of a central fixation cross (1 x 1 cm). Responses were executed by pressing the “z” or “-” key of a standard Italian keyboard with the left or right index finger, respectively.

5.2.1.3 Procedure

The experimenter explained that the study was aimed at investigating the effect of different cognitive styles on task performance. To this aim, participants were informed that they would perform three separate tasks. After completion of the first two cognitive tasks, participants were required to respond to a brief questionnaire while the experimenter left the room to score the participants’ performance. When the experimenter returned to the room, she communicated to the participants their results, telling them that they displayed either the same cognitive style (same-group condition) or two different cognitive styles (different-group condition). Even though participants believed that the style assignment was based on their performance to the two tasks, it was random.

Participants were then provided with information about their cognitive styles and informed that they would have to perform a task together. In the same group condition, the experimenter emphasized that, based on their cognitive style, participants were expected to display a very similar performance. In the different-group condition, the experimenter emphasized that, based on their different cognitive styles, performance on the following task was expected to be remarkably different.

Participants were then required to perform a Simon task jointly, sitting side-by-side in front of the same computer screen (for a schematic representation of the joint Simon task, see Figure 4.1 in Chapter 4). Each participant was instructed to respond to only one stimulus color. For half of the pairs, the participant sitting on the right chair was instructed to press the right key to the green stimulus whereas the participant sitting on the left chair was instructed to press the left key to the red stimulus. The other half pairs experienced the opposite stimulus–response mapping.

A trial began with the presentation of the fixation cross at the center of a black background. After 1 s, the stimulus appeared to the right or to the left of fixation and remained visible for 800 ms. Maximum time allowed for a response was 1 s. A response terminated the trial and the inter-trial interval was 1 s.

The Simon task consisted of 20 practice trials and 160 experimental trials that were divided into two blocks of 80 trials each. For half of the trials, stimulus and response location corresponded (corresponding trials), and for the other half, they did not correspond (non-corresponding trials).

At the end of the experiment, participants were asked to complete a post-experiment questionnaire (see Appendix E) to rate the experimental situation using a 7-point bipolar semantic differential scale on the following dimensions: easy versus difficult (1 = easy, 7 = difficult), pleasant–unpleasant (1 = pleasant, 7 = unpleasant), positive–negative (1 = positive, 7 = negative), and cooperative–competitive (1 = cooperative, 7 = competitive). On the whole, the experiment consisted of a 30-min session.

5.2.2 Results

Error trials were less than 1% and were excluded from further analyses. Correct response times (RT) were entered into a 2 x 2 repeated-measures analysis of variance (ANOVA) with *Condition* (same-group vs. different-group condition) as between-subjects factor and *stimulus–response Correspondence* (corresponding vs. non-corresponding trials) as within-subjects factor. Newman-Keuls post-hoc test was also conducted on significant interactions.

The effect of *Condition* did not reach significance [F (1, 30) = 1.25, MSe = 3761, p = .28]. There was a main effect of *Correspondence* [F (1, 30) = 40.92, MSe = 47, $p < .001$], with faster RTs in corresponding (M = 329 ms) than in non-corresponding trials (M = 340 ms). Data are shown in Figure 5.1. The advantage for corresponding responses was evident in both experimental conditions with a 13-ms Simon effect in the same-group condition and a 10-ms effect in the different-group condition. Even though the effect was numerically smaller in the different-group condition than in the same-group condition, this difference did not reach statistical significance, as indicated by the lack of a significant *Correspondence* x *Condition* interaction [*F* (1, 30) = 1.01, *MSe* = 47, *p* = .32].

As regards the scores obtained from the bipolar semantic differential scale, overall participants judged the situation as easy (*M* = 1.93, *SD* = 1.13), pleasant (*M* = 2.19, *SD* = 1.03), positive (*M* = 1.69, *SD* = .86), and cooperative (*M* = 2.87, *SD* = 2.03). A *t* test was used to assess whether the scores significantly differed from the neutral point (4). For the participants in the same-group condition, all judgments were significantly lower than the neutral point (*p* < .001). For the participants in the different-group condition, only the cooperative–competitive dimension obtained a score equal to 4, [*t* (1, 15) = -0,81, *p* = .43], while scores in the other dimensions were lower than 4 (*p* < .01). A *t* test for independent samples indicated that for all dimensions, the scores were significantly lower for the same-group condition (*p* < .05).

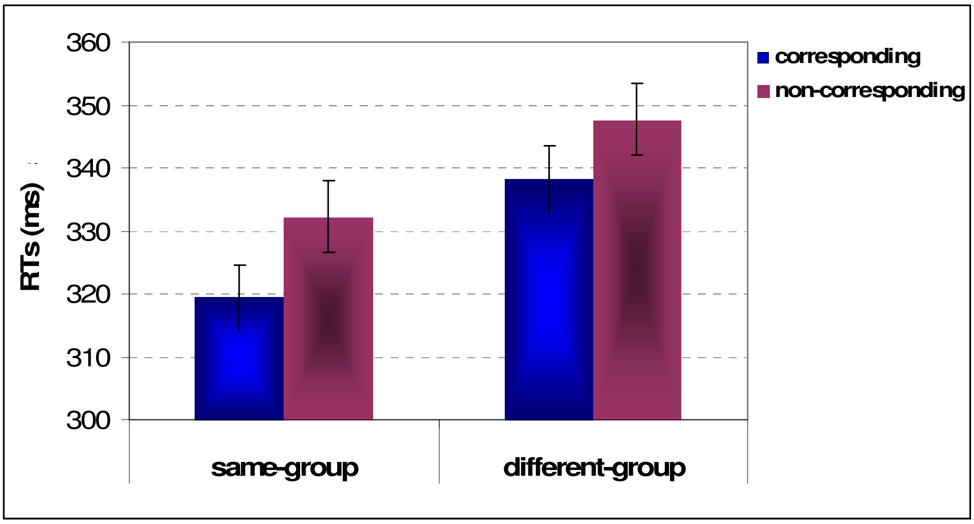


Figure 5.1 Study 2, Experiment 4: reaction times (ms) for corresponding and non-corresponding trials as a function of group membership (same group vs. different group). Error bars show standard errors of the means.

5.2.3 Discussion

Our results indicate that shared representations, as indexed by the joint Simon effect, emerge even when participants believe to perform the task along with a member of a different group. The observation that under the same-group condition, the joint Simon effect is comparable to the effect reported in previous studies (Sebanz et al. 2003; Milanese et al. 2010), clearly demonstrates that simply perceiving themselves as part of the same group as a co-actor does not enhance the creation of shared representations.

Actually, even though the paradigm proposed by Tajfel et al. (1971) constitutes the conceptually more related reference for the experimental situation that we used, it is important to emphasize that a relevant element marked the difference between the present experimental situation and the one traditionally used in the minimal cues paradigm. In fact, in the conditions studied by Tajfel and colleagues, participant after having received the information concerning his/her group membership (i.e., category of those who prefer Klee vs. Kandinsky paintings) undertakes the task of giving monetary rewards to two persons only distinguishable on the basis of their categorical membership. In this situation, participant becomes "outside" to the judged system even if aware of sharing a categorical affiliation with one of the two persons. In the case of the experimental situation that we designed, participant after has been arbitrarily assigned to the category of synesthetic or differentiator is engaged in a motor decision task in which he/she is compared directly with a partner. Therefore, in this case participant is "intern" to the judged system. Given the situation provided by the joint Simon effect, namely the possible integration of others' actions in one own plan, it becomes important the degree of salience with which participant feels to belong to a given category. According to the "self-categorization theory" (Turner, 1987), categorical salience is determined by two factors: the accessibility of a category and the adequacy of that category in the account of the stimuli present in a context. With regard to accessibility, participants performed the

Simon task immediately after giving them the information about their categorical membership; this element gave us a plausible security that that information should maintain salient this type of categorization. As regards the adequacy, we had chosen a generic and ambiguous system of categorical attribution (synesthetic vs. differentiator) that seemed to fit the characteristics of the task that couples of participants were about to execute: categorical labels assigned to participants might seem appropriate in favor different strategies of interaction with the partner during the execution of that particular type of task. The results obtained do not have revealed any difference in performance of participants belonging to two different categories, hence suggesting that a simple self-categorization condition, as the one we used, was not sufficient to activate different strategies of interaction on the basis of the sharing or not of the same categorical labels with the partner during the joint Simon task.

5.3 Experiment 5

Differently from Tajfel and colleagues (Tajfel et al., 1971), other authors posit that individuals perceive themselves as part of the same group if they are aware of belonging to a category, share a common goal, and perceive themselves as positively interdependent with respect to goals and means to attain these goals, and thus they had to cooperate (Rabbie & Horwitz, 1969). In a study designed to investigate the influence of social categorization on helping behavior, Gaertner and Dovidio (2000) founded that, when an identity of belonging to the same group was inducted, helping behaviors increased significantly towards persons previously perceived as members of an outside group. Although factors such as the degree of similarity and the empathic relationship could play a role, the responsible of the helping behaviors was the process of re-categorization, that made persons as members of a single common group. In the same direction were the results obtained in a study conducted by Kramer and Brewer (1984). In a situation of decision making regarding the use and consume of a shared and depleted natural resource, participants exerted a more severe self-control when moving from belonging to different groups toward a situation in which a superordinate group identity was made salient.

Based on these empirical findings, Experiment 5 was aimed at assessing whether the differentiation between ingroup and outgroup obtained by manipulating the interdependence experienced by two acting individuals is effective in modulating the arising of the joint Simon effect. This would indicate that the activation of shared representations is sensitive to complex ingroup–outgroup distinctions.

It is important to note that positive interdependence implies cooperation since individuals need to work together to attain a common goal; conversely, negative interdependence implies competition since individuals work one against the other to attain a personal goal (Deutsch, 1949, 1962). As mentioned above, the effects of competition and cooperation on the emergence of shared representations have been recently investigated by Ruys and Aarts (2010). Although we find the results of this study interesting, we believe that their competitive condition does not satisfy the widely accepted definition of competition, since a given number of participants was randomly selected for the reward. Instead, competition is generally defined as involving one individual attempting to outperform another in a zero-sum situation, namely in a situation in which the gain or loss of a participant is perfectly balanced by the gain or loss of another participant (Kelley & Thiabut, 1969). Accordingly, in the present experiment, participants were randomly coupled and asked to perform the Simon task together, each responding to one stimulus color. Under the positive interdependence (cooperative) condition, participants were told that the couple with the fastest and most accurate responses would receive an economic reward. Under the negative interdependence (competition) condition, they were told that the participant of the couple with the fastest and most accurate responses would receive an economic reward.

5.3.1 Methods

5.3.1.1 Participants

Thirty-two new undergraduates students from the University of Bologna (18 males and 14 females) with a mean age of 22.3 years (age range: 19–34 years), took part in the Experiment 5 for monetary reward (5 €). All subjects were right-handed and reported normal or corrected-to-normal vision. All were naive as to the purpose of the experiment and gave written informed consent. Participants were randomly coupled and each couple was randomly assigned to one of two experimental conditions.

5.3.1.2 Apparatus, stimuli, and procedure

Stimuli were the same as those used in the Simon task of Experiment 4.

Participants were required to perform the Simon task jointly. Half couples were assigned to the cooperative condition, and the other half were assigned to the competitive condition. In the cooperative condition, each couple of participants was placed in competition against the other couples. Participants in the couple were told that the best-performing couple, in terms of both speed and accuracy, would receive a ten Euro reward (five Euro to each participant). The experimenter emphasized the importance of coordinating their efforts as they worked on the task to attain the goal. In the competitive condition, participants in the couple were placed in a competition against one another. They were told that at the end of the experiment, the best-performing participant, in terms of both speed and accuracy, would receive a five Euro reward.

The experiment consisted of 20 practice trials and 260 experimental trials that were divided into two blocks.

At the end of the experiment, participants were asked to complete a post-experiment questionnaire to rate the experimental situation using a 7-point bipolar scale on the following dimensions: easy versus difficult (1 = easy, 7 = difficult), pleasant–unpleasant

(1 = pleasant, 7 = unpleasant), positive–negative (1 = positive, 7 = negative), and cooperative–competitive (1 = cooperative, 7 = competitive).

On the whole, the experiment consisted of a 20-min session.

5.3.2 Results

Data were treated as in previous experiment. Error trials were less than 1% and were excluded from further analyses. Correct RTs were entered into a 2 x 2 repeated measures ANOVA with *Condition* (cooperative couples vs. competitive couples) as between-subjects factor and *stimulus–response Correspondence* (corresponding vs. non corresponding trials) as within-subjects factor. Newman-Keuls post-hoc test was also conducted on significant interactions.

Condition did not reach statistical significance [*F* (1, 30) = 1.65, *MSe* = 3837, *p* = .21]. There was a main effect of *Correspondence* [*F* (1, 30) = 20.88, *MSe* = 53, *p* < .001], with faster RTs in corresponding (*M* = 317 ms) than in non-corresponding trials (*M* = 324 ms). Most important, there was a significant *Condition* x *Correspondence* interaction [*F* (1, 30) = 8.85, *MSe* = 53, *p* < .01]. Data are shown in Figure 5.2. The Newman–Keuls test showed that the advantage for corresponding responses was significant in cooperative couples (14 ms) but not in competitive couples (3 ms). An analysis with the magnitude of the effect as dependent variable indicated that these two values significantly differed [*F* (1, 30) = 8.84, *p* < .01].

As regards the scores obtained from the bipolar semantic differential scale, overall participants judged the situation as easy (*M* = 1.87, *SD* = .79), pleasant (*M* = 2.37, *SD* = 1.52), positive (*M* = 2.03, *SD* = 1.38), and cooperative (*M* = 3.56, *SD* = 2.39). For cooperative couples, all judgments were lower than the neutral point 4 (*p* < .03). For competitive couples, judgments on the cooperative–competitive dimension were equal to 4 [*t* (1,15) = .47, *p* = .64], all other judgments were lower than 4 (*p* < .001). Importantly, competitive couples tended to judge the situation as more competitive than cooperative couples (2.8 vs. 4.3 for cooperative and competitive couples, respectively), [*t* (1, 30) = 1,84, *p* = .07]. No other difference between couples reached statistical significance (*p* > .10).

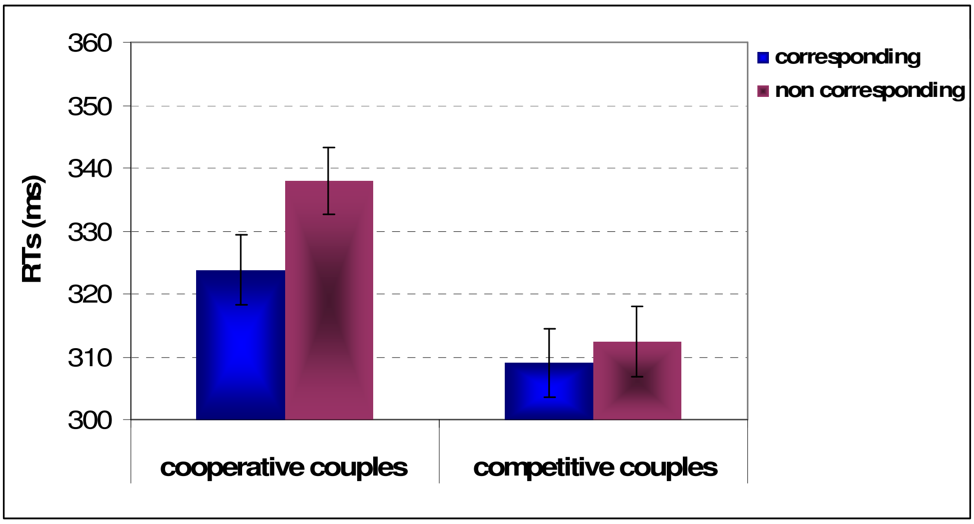


Figure 5.2 Study 2, Experiment 5: reaction times (ms) for corresponding and non-corresponding trials as a function of interdependence (cooperative couples vs. competitive couples). Error bars show standard errors of the means.

5.3.3 Discussion

These results indicate that the activation of shared representations, as indexed by the joint Simon effect, occurs only when individuals cooperate but not when they compete. This result is inconsistent with the finding by Ruys and Aarts (2010) showing that shared representations emerge when individuals attend to the co-actor intentions, irrespective of the cooperative or competitive nature of the interaction. The observation that both groups perceived the experimental situation as equally positive and pleasant allows us to exclude that differences in performance could be due to emotional factors.

5.4 Comparison between Experiments 4 and 5

To compare the magnitude of the Simon effect, the correct RTs of Experiment 4 and Experiment 5 were entered into a one-way ANOVA, with *Condition* (same-group, different-group, cooperation, competition) as between-subjects factor.

The joint Simon effect was significantly higher in the same-group (13 ms, $p = .019$) and in the cooperative conditions (14 ms, $p = .017$) compared to competitive couples (3 ms), [F (3, 60) = 3.86, MSE = 100, $p = .01$] (Figure 5.3).

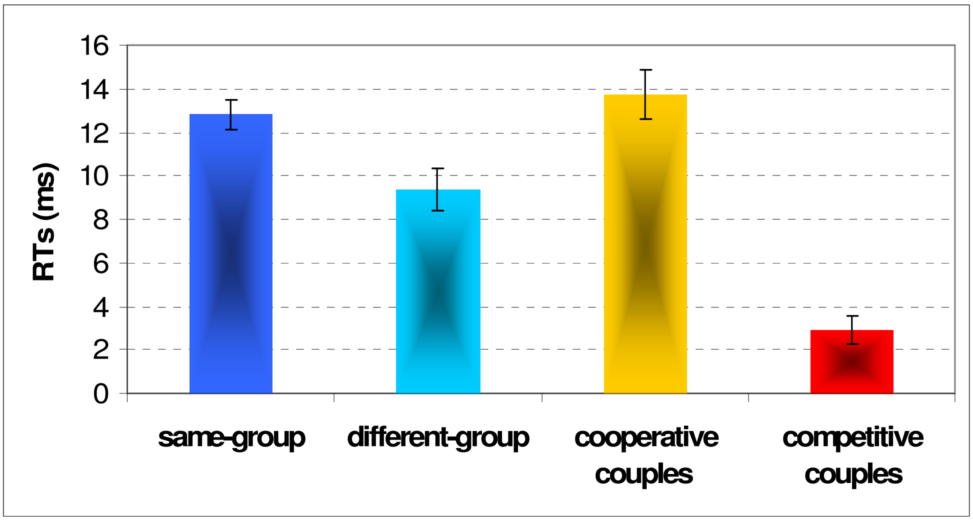


Figure 5.3 Study 2, Comparison Experiments 4 and 5: reaction times (ms) for joint Simon effect as a function of *Condition* (same-group, different-group, cooperative couples, competitive couples). Error bars show standard errors of the means.

5.5 General Discussion

Previous studies suggest that shared representations emerge whenever complementary actions are distributed across different individuals (see findings reviewed in Chapter 4; e.g., Sebanz et al., 2003). The joint Simon effect has indeed been taken as an indication that when two individuals perform the Simon task each responding to one stimulus color, each individual forms a representation of both action alternatives. One open question is whether shared representations are automatically formed any time individuals act in a social context or whether they depend on the perceived psychological connectedness between co-acting individuals. To address this question, we assessed whether joint actions, as indexed by the joint Simon effect, are modulated by perceived group membership and by the strength of the differentiation between ingroup and outgroup (Iani et al., 2011; Anelli et al., in press a).

Our results indicate that mere social categorization of co-acting participants into groups did not modulate the emergence of shared representations that were evident even when participants believed to perform the task along with an individual belonging to a different social group (Experiment 4). On the contrary, joint action was influenced by the type of interdependence between co-actors. Specifically, shared representations were not activated when co-acting individuals were required to compete one against the other and their performance was negatively interdependent (Experiment 5).

Although research using Tajfel's (1970) minimal group paradigm suggests that social categorization is a sufficient antecedent of ingroup–outgroup distinction and of consequent ingroup-favoring discrimination, some authors raised questions about whether social categorization alone is sufficient for group formation and intergroup discrimination. For instance, drawing on Lewin's idea (1948), Rabbie and Horwitz (1969) proposed that a perceived positive interdependence is the precondition for group formation and for subsequent ingroup–outgroup differentiation. Our findings may contribute to this long-lasting debate. Indeed, the finding that only the ingroup–outgroup distinction produced by negative interdependence was strong enough to disrupt the emergence of shared representations favors the view that ingroup–outgroup discrimination processes are enhanced by perceived interdependence. To make this conclusion more plausible, in a possible future study could be appropriate to replicate the Experiment 4 emphasizing also in perceptual terms the role of participants' categorical membership in the Simon task, namely providing elements that mark in a visible perceptually way the participants' membership to a same or different group.

Notably, the finding of a joint Simon effect when participants were required to cooperate and its absence when they were required to compete is at odd with the view proposed by Ruys and Aarts (2010) that shared representations emerge even in competitive contexts as long as individuals attend to the intentions of the co-actor. Indeed, under the competitive condition used in our study, since the participants' goal was to outperform their co-agents, they were likely to observe and pay attention to the others' actions and intention to monitor their progress toward their goal. More specifically, according to the literature on achievement goals (for a review, see Poortvliet & Darnon, 2010), people whose aim is to outperform others, as occurs in competitive situations, develop an "other-referenced focus" since, to monitor their progress toward the goal, they tend to compare their performance with the performance of others. On the contrary, people whose aim is to improve one's own performance develop a "self-referenced focus" since they tend to compare their present performance with their previous performances. Nevertheless, no joint Simon effect was observed under the competitive condition. On the contrary, a joint Simon effect was observed under the cooperative condition.

Even though the findings of the present study do not support the view that shared representations emerge any time individuals act in a social context, they suggest that the tendency to integrate the co-actor's action into our own action system is quite strong. Such a conclusion is indeed also suggested by the results of those studies showing that the joint Simon effect occurs even when individuals believe to perform the task along with another person sitting in a different room (e.g., Tsai et al., 2008; but see Welsh et al., 2007 for different results). The finding of a joint Simon effect under both conditions of Experiment 4 and the observation that it was of comparable magnitude under these two conditions and under the cooperative condition of Experiment 5 seem to suggest that when acting in a social context, by default, individuals may perceive positive interdependence with co-acting individuals, even when cooperation is not explicitly requested and ingroup–outgroup differentiation is not supported by negative interdependence (i.e., competition). This result is consistent with Tomasello and colleagues (2005) who argue that human beings are inclined to share goals and intentions. According to the authors, this uniquely human ability is the result of the interaction between two different capacities. The first is the ability to “read” the others’ intentions through observation of their behavior, namely human beings would be able to understand and represent others as agents oriented to achieve goals. The second ability concerns the motivation to share intentions and cooperate with others, an ability that expresses itself in cooperative behavior, emerges very early in the individuals, and constitutes an important basis for later cognitive development. Lastly, the perception of positive interdependence may enhance the willingness to invest in the interaction (Poortvliet & Darnon, 2010), hence paving the way for the emergence of shared representations. Differently, when the other represents an obstacle toward the attainment of a personal goal, as occurs in explicit competitive situations, individuals may be less willing to coordinate their efforts, to depend on, and to be influenced by the other’s actions, this blocking the integration of self and other’s action.

CHAPTER VI

STUDY 3:

JOINT ACTION AND CARRY-OVER EFFECT OF INTERDEPENDENCE

6.1 Introduction

Engaging an interaction with other individuals is a fundamental part of our daily life and many factors can influence these relationships. Several evidence from social psychology clearly demonstrates that factors such as prejudice, competition, and cooperation interact, and influence the social context. In this regard, it seems very interesting the "Realistic group-conflict theory" which claims that, when two groups are in competition for limited resources, the potential success of one group menaces the comfort and interests of the other one, resulting in negative outgroup attitudes (Campbell, 1965; Sherif, 1966; Sherif & Sherif, 1969; Levine & Campbell, 1972). These resources may be not only tangible (e.g., money), but may also involve power or control (e.g., political power). When the goals of different groups are complementary, relations between the groups will be positive; conversely, when conflicting goals exist, relations will be negative. The resulting conflict may increase ingroup solidarity (i.e., toward the group the individual is a member of), which amplifies the ingroup/outgroup distinction and creates intergroup hostility.

To test realistic group-conflict theory, in their seminal work Sherif and colleagues (Sherif et al., 1961) divided children in a summer camp program into two separate groups and involved them in competitive activities (Phase 1). Since these activities permitted victory of only one group over the other, one group's success precluded the success of the other one. Until competition continued, hostility between the groups increased (Phase 2). The bias between the groups decreased only when common goals that required intergroup cooperation were introduced (Phase 3).

Besides this seminal study, other findings demonstrated that incompatible goals and perceived competition between groups are linked to: negative outgroup attitudes, stereotyping, intergroup threat, and prejudice (Langford & Ponting, 1992; Tougas, Brown, Beaton, & Joly, 1995; Watts, 1996; Beaton & Tougas, 2001; Zarate, Garcia, Garza, & Hitlan, 2004; for a review, see Riek, Mania, & Gaertner, 2006). Indeed, according to realistic group-conflict theory, conflicts of interest and thus negative interdependence between groups induce prejudice and social discrimination because such conflicts lead to intergroup threat. For increased prejudice to occur, perceiving a conflict or a competition is sufficient. Moreover, higher levels of prejudice, even towards an outgroup that was not involved in the competition, can be caused by both recollection of a competition from memory and participation in a competition. In this regard, Sassenberg, et al. (2007) argued that thinking about or going through a competition might cause the so-called "carry-over effect of competition", namely a subsequent intergroup situation might be experienced as more competitive.

In line with this assumption, Stapel and Koomen (2005) showed that a "difference" focus was activated by competitive situation, while a "similarity" focus was activated by cooperative situation. In fact, different situations can cause the onset of different mindsets, namely of "cognitive procedures related to how one chooses between various goal alternatives or to the planning of actions one must take in order to attain a chosen goal" (Gollwitzer, Heckhausen, & Steller, 1990, p. 1120). When a "competition mindset" is activated in one context, the encountered intergroup contexts can be perceived as more competitive. Hence, a competition mindset should cause more prejudice, higher perceived negative interdependence, and increased outgroup homogeneity, compared to when a cooperation mindset or no specific mindset is activated (e.g., Carnevale & Probst, 1998; Corneille, Yzerbyt, Rogier, & Buidin, 2001).

As claimed in the previous chapters, the importance of the social context and its influence on the involved co-actors are becoming more important within the cognitive sciences, as well as for social psychology. In particular, the topic of joint action will be central even in this chapter, using once again the joint Simon paradigm as a tool to measure the emergence of shared representations. As we shall see, the present study is closely related to the investigation presented in the previous chapter. More specifically, the Study 3 (Anelli et al., in preparation a) is aimed to further assess whether shared representations are modulated by group membership, in particular by the interdependence experienced by two acting individuals, and whether the induction of cooperative or competitive condition leads to the emergence of a sort of carry-over effect.

Relevant to our aims, recent studies focused on how the joint Simon effect can be modulated by social factors. Briefly resuming some findings widely discussed in Chapters 4 and 5, some studies clearly demonstrate that shared representations, as indexed by the joint Simon effect, emerge after the induction of a positive but not of a negative mood (Kuhbandner et al., 2010); they are activated after interaction between two co-acting individuals with positive valence but not after interaction with negative valence (Hommel et al., 2009); they depend on whether participants attended to the intentions of the other, particularly in interdependent condition compared to independent one (Ruys & Aarts, 2010).

As discussed in Chapter 5, in our previous work (Iani et al., 2011; Anelli et al., in press a), we investigated the influence on joint actions of perceived group membership of co-acting participants and the strength of the differentiation between ingroup and outgroup, manipulating minimal cues (i.e., belonging of participants to the same vs. to different group; Experiment 4) and the perceived interdependence (i.e., cooperative vs.

competitive interdependence; Experiment 5). Our results indicate that mere social categorization of co-acting participants into groups did not influence the emergence of shared representation, as indexed by the joint Simon effect, which was present even when participants perform the task with an individual belonging to a different social group. In contrast, the emergence of shared representation was modulated by the kind of interdependence between co-actors, as it was activated when participants were required to cooperate and their performance was positively interdependent, while it was absent when they had to compete and their performance was negatively interdependent.

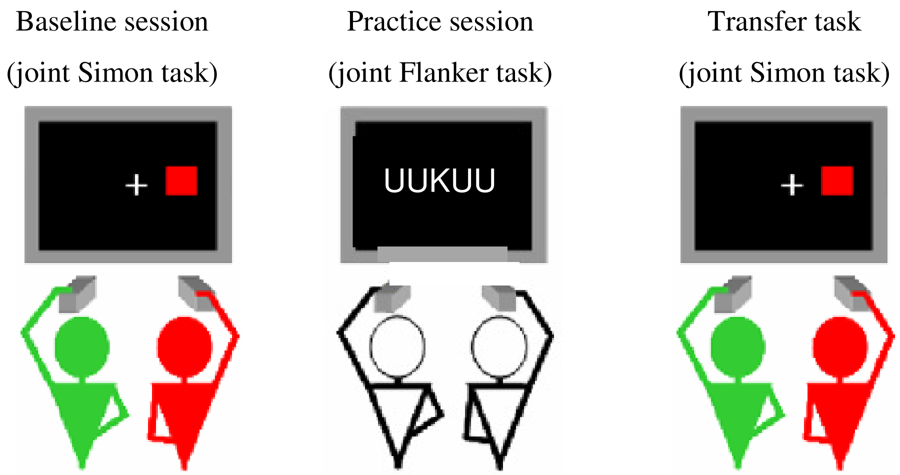
Overall, previous studies, both from social and cognitive psychology, provide clear evidence of the social context importance on the participants' performance; namely, factors such as competition and cooperation seem to play a relevant role in the process of social interaction.

Starting from these assumptions, we ran three experiments in which couples of participants were required to perform a joint Simon task following a task in which they experienced different kinds of perceived interdependence. More specifically, we aimed to measure the influence exerted by shared cooperative or competitive practice on subsequent performance. Moreover, we assessed the duration of the practice effects. We used the same manipulation employed in our previous work (Chapter 5, Experiment 5; Iani et al., 2011, Experiment 2; Anelli et al., in press a, Experiment 2), namely we manipulated whether the goals of the two participants were positively related (i.e., the success of one individual made also the success of the other more likely) or whether they were negatively related (i.e., the success of one individual made the success of the other less likely).

To this aim, we used a modified version of the transfer-of-learning paradigm, introduced for the first time in a spatial stimulus–response (S–R) correspondence task by Proctor and Lu (1999). The authors showed that it was possible to modulate performance on the Simon task (i.e., transfer task) by asking participants to perform before a spatial compatibility task (i.e., practice task) with incompatible mapping (i.e., responding to the right stimulus with the left key and vice versa). Specifically, in the transfer task the Simon effect was reduced, absent or even reversed, since responding with incompatible mapping in the practice task strengthens the non-corresponding association between a stimulus and a response, and this association affects performance even when the task is changed (Proctor & Lu, 1999; Tagliabue, Zorzi, Umiltà, & Bassignani, 2000; Iani, Rubichi, Gherri, & Nicoletti, 2009). In two recent studies, introduced in Chapter 4 about the importance of learning on shared representations, Milanese and colleagues (Milanese et al., 2010, 2011) created a "social" version of this paradigm (i.e., a joint transfer-of-learning paradigm), showing the influence of joint task performance on implicit learning and the transfer of this learning to subsequent performance.

In the present study, we combined two well-known paradigms of cognitive psychology: the joint Simon task developed by Sebanz and colleagues (Sebanz et al. 2003) and the joint transfer-of-learning task developed by Milanese and colleagues (Milanese et al., 2010). This choice allowed us first of all to assess whether and to what extent performing a competitive or a cooperative task with a co-actor shapes the way a subsequent task is executed, comparing the participants' performance before and after the introduction of a condition of interdependence, and second to measure the duration of this potential effect. To these aims, we ran three experiments in which participants performed a joint Simon task before and after practicing a non-spatial task, in order to be sure that spatial characteristics of the practice task did not affect performance in the transfer task, as it might happens with a spatial S–R correspondence task. For this reason, we choose the Flanker task (Eriksen & Eriksen, 1974) in a social version (i.e., a joint Flanker task; Atmaca, Sebanz, & Knoblich, 2011). In more detail, in Experiment 6, participants performed the joint Simon task in a neutral condition (i.e., without any competitive or cooperative instruction; baseline session), the joint Flanker task in a cooperative condition (practice session), and the joint Simon task in a neutral condition (transfer session); in Experiment 7, they performed the joint Simon task in a neutral condition (baseline session), the joint Flanker task in a competitive condition (practice session), and the joint Simon task in a neutral condition (transfer session); finally, in Experiment 8, they performed the joint Simon task in a neutral condition (baseline session), the joint Flanker task in a competitive condition (practice session), and the joint Simon task in a cooperative condition (transfer session), (see Figure 6.1 for the experimental design).

On the basis of reviewed findings, derived both from studies of cognitive and social psychology, we hypothesize the emergence of a significant joint Simon effect when participants practice a cooperative interdependence (Experiment 6). Instead, we predict that the joint Simon effect would be reduced or even absent when participants experience a competitive interdependence in the practice session (Experiment 7). Finally, as regards the duration of the predicted competitive practice effect (Experiment 8), we can advancing two possible hypotheses: if a competitive practice has a long-lasting effect, we should obtain a reduced or null joint Simon effect even when participants experience a cooperative condition after a competitive practice; instead, whether the competitive practice only produces a short-lasting effect, we should register a significant joint Simon effect when participants experience a cooperative condition after a competitive practice. Stated differently, we hypothesize that a carry-over effect should emerge after a competitive interdependence, whereas no carry-over effect should be present after a cooperative interdependence.



Baseline session (joint Simon task)

Practice session (joint Flanker task)

Transfer task (joint Simon task)

Figure 6.1 Schematic representation of the experimental design used in the Study 3. In the three sessions participants are seated side-by-side in front of a monitor. In the baseline and transfer sessions participants perform a joint Simon task, whereas in the practice session they perform a joint Flanker task.

6.2 Experiment 6

The aim of the present experiment was to assess whether a cooperative practice performed alongside another person can modulate performance in a subsequent joint Simon task. To this end, participants were required to perform a joint Simon task in a neutral condition (i.e., without any competitive or cooperative instruction) before and after performing a practice with a cooperative joint Flanker task (i.e., receiving cooperative instruction).

6.2.1 Methods

6.2.1.1 Participants

Sixteen undergraduates students from the University of Modena and Reggio Emilia (3 males and 13 females) with a mean age of 22.4 years (age range: 20–32 years) took part in the experiment for course credits. All subjects were right-handed and reported normal or corrected-to-normal vision. All were naive as to the purpose of the experiment and gave written informed consent. Once recruited, they were randomly paired.

6.2.1.2 Apparatus and timuli

During the experiment, participants sat side-by-side in front of a 17-inch colour monitor (the eye-to-screen distance was approximately 60 cm). E-Prime 2.0 software was used for presenting stimuli and collecting responses.

Stimuli in the joint Simon task were red or green solid squares (2 x 2 cm), presented 4.5 cm to the left or to the right of a central fixation cross (1 x 1 cm). Stimuli in the joint Flanker task were arrays of five letters (2.5 x 1 cm), presented centrally. In both tasks, responses were executed by pressing the “z” or “-” key of a standard Italian keyboard with the left or right index finger, respectively.

6.2.1.3 Procedure

The experiment consisted of three consecutive sessions separated by a 5-min interval: a baseline session, a practice session, and a transfer session. In the baseline and transfer sessions participants performed a Simon task, whereas in the practice session they performed a Flanker task. Both Simon and Flanker tasks were carried out jointly with participants sitting side-by-side in front of the same computer screen.

In the first (baseline session) and in the third session (transfer session), each participant was instructed to respond to only one stimulus colour. For half of the pairs, the participant sitting on the right chair was instructed to press the right key to the red stimulus whereas the participant sitting on the left chair was instructed to press the left key to the green stimulus. The other half experienced the opposite mapping. Participants had to make speeded discriminative responses to the colour of the square and to ignore the location of the stimulus. The colour and location of the stimulus varied randomly but both colours and locations appeared equally often across the experiment. For each participant, two types of trials were included in the experiment: “corresponding” trials, in which the stimulus appeared on the same side of the screen as the side of the correct response, and “non-corresponding” trials, in which the stimulus appeared on the side opposite to that of the correct response.

In the second session (practice session), the two participants performed a modified version of the Flanker task (Eriksen & Eriksen, 1974), namely a joint Flanker task (Atmaca et al., 2011) in a cooperative condition. Each couple of participants was placed in competition against the other couples and it was told that the best performing couple, in terms of both speed and accuracy, would receive a ten Euro reward (five Euro to each participant). In other words, participants were required to collaborate in order to achieve the common goal. We used the same instructions employed in the cooperative condition of the Experiment 5. To note, the experimenter informed that the cooperation concerned only that session and not the whole experiment. Participants were presented with arrays of five letters, with the letter in the middle position constituting the target letter. Each participant was instructed to respond to two of four target letters by pressing the response key (left or right key-press). Targets were the letters H, K, S, and C, with H and K assigned to one key, and S and C assigned to the other key. The letters H, K, S, C, and U served as flankers. The combination of target and flanker letters resulted in four stimulus types (see Appendix F), namely targets are surrounded by distracting flankers that are either: the same as the target (identical trials), perceptually different from the target but refer to the same response/same participant (compatible trials), perceptually different and refer to the opposite response/other participant as the target (incompatible trials), or perceptually different and do not refer to any response/any participant (neutral trials). The combinations of target pairs (H, K vs. S, C) and response keys (left vs. right) were counterbalanced across participant.

In both tasks, a trial began with the presentation of the fixation cross at the center of a black background. After 1000 ms the stimulus appeared. In the Simon task, the stimulus appeared to the right or to the left of the fixation cross, remained visible for 800 ms, and the maximum time allowed for a response was 1000 ms. In the Flanker task, the stimulus appeared at the center, remained visible for 600 ms, and the maximum time allowed for a response was 1000 ms. In both tasks, a response terminated the trial and the inter-trial-interval was 600 ms.

Both baseline and transfer sessions consisted of 12 practice trials and 160 experimental trials, divided into two blocks of 80 trials each. The practice session consisted of 24 practice trials and 288 experimental trials that were divided into three blocks of 96 trials each. On the whole, the experiment consisted of a 40-min session.

6.2.2 Results

Here and in the following experiments we report only the data for the Simon tasks (baseline and transfer sessions).

Error trials (1 % in the baseline session and 1 % in the transfer session) were excluded from further analyses. Correct response times (RTs) were submitted to a 2 x 2 repeated-measures analysis of variance (ANOVA) with *Session* (baseline vs. transfer) and *stimulus–response Correspondence* (corresponding vs. non-corresponding trials) as within-subjects factors. Fisher's LSD post-hoc test was also conducted on significant interactions.

Correspondence produced a significant effect on RTs [*F* (1, 15) = 8.29, *MSe* = 329, *p* = .01], showing that participants were faster in corresponding (*M* = 341 ms) than in non-corresponding (*M* = 354 ms) trials. Both the effect of *Session* [*F* (1, 15) = 1.51, *MSe* = 926, *p* = 0.24] and the interaction between *Session* and *Correspondence* [*F* (1, 15) = 0.95, *MSe* = 18, *p* = 0.35] did not reach significance. Data are shown in Figure 6.2. The advantage for corresponding responses was evident in both sessions, with a 14-ms joint Simon effect in the baseline session and a 12-ms effect in the transfer session. As indicated by the lack of a significant interaction between the two factors, even though the effect was numerically smaller in the third session than in the first one, this difference did not reach statistical significance.

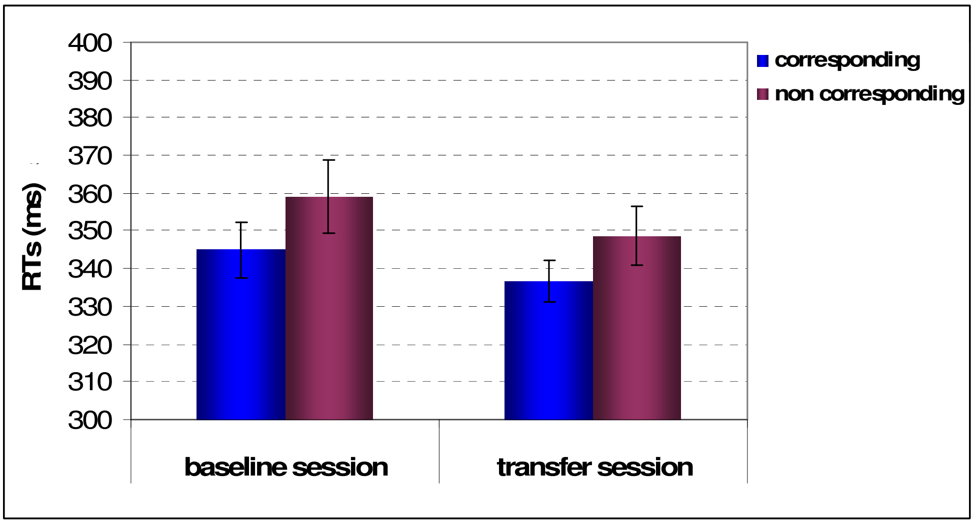


Figure 6.2 Study 3, Experiment 6: reaction times (ms) for the baseline and transfer sessions as a function of *stimulus–response Correspondence*. Error bars show standard errors of the means.

6.2.3 Discussion

The results of the Experiment 6 indicate that after a cooperative practice task the joint Simon effect is still present. Hence, a cooperative training performed jointly with another person does not seem to affect the performance on a subsequent Simon task. For all three experiments, we decided to discuss in more detail the results in the General Discussion section.

6.3 Experiment 7

The aim of the present experiment was to investigate what happens when participants performed a competitive practice, instead of a cooperative one, and to assess whether this kind of practice can different modulate the performance in a subsequent joint Simon task. To this end, as in the Experiment 6, participants were required to perform a joint Simon task in a neutral condition (i.e., without any competitive or cooperative instruction) before and after performing a joint practice. Differently from the previous experiment, they practiced a competitive joint Flanker task (i.e., receiving competitive instruction).

6.3.1 Methods

6.3.1.1 Participants

Sixteen new undergraduates students from the University of Modena and Reggio Emilia (4 males and 12 females) with a mean age of 24.3 years (age range: 22–27 years) took part in the Experiment 7 for course credits. All subjects were right-handed and reported normal or corrected-to-normal vision. All were naive as to the purpose of the experiment and gave written informed consent. Once recruited, they were randomly paired.

6.3.1.2 Apparatus, stimuli, and procedure

Apparatus, stimuli, and procedure were the same as Experiment 6 except for the following.

During the practice session participants performed a joint Flanker task in a competitive condition instead of in a cooperative one. Participants in the couple were placed in a competition against one another and they were told that at the end of the experiment the best performing participant, in terms of both speed and accuracy, would receive a five Euro reward. In other words, participants were required to compete in order to achieve the goal. We used the same instructions employed in the competitive condition of the Experiment 5. To note, the experimenter informed that the competition concerned only that session and not the whole experiment.

6.3.2 Results

Data were treated as in previous experiment. Error trials (1 % in the baseline session and 1 % in the transfer session) were excluded from further analyses. Correct RTs were submitted to 2 x 2 repeated-measures ANOVA with *Session* (baseline vs. transfer) and *stimulus–response Correspondence* (corresponding vs. non-corresponding trials) as within-subjects factors. Fisher's LSD post-hoc test was also conducted on significant interactions.

The main effect of *Correspondence* was significant [F (1, 15) = 7.24, MSe = 136, p = .02]. Participants were faster in corresponding (M = 332 ms) than in non-corresponding (M = 340 ms) trials. The effect of *Session* did not reach significance [F (1, 15) = 0.01, MSe = 671, p = .98]. Most important, the interaction between *Session* and *Correspondence* was significant, indicating that the Simon effect differed in the two sessions [F (1, 15) = 11.06, MSe = 42 , p < .01]. Data are shown in Figure 6.3. The Fisher's LSD test revealed that the Simon effect observed in the baseline session was significant (13 ms), while a reduced and non significant effect (2 ms) was evident in the transfer session.

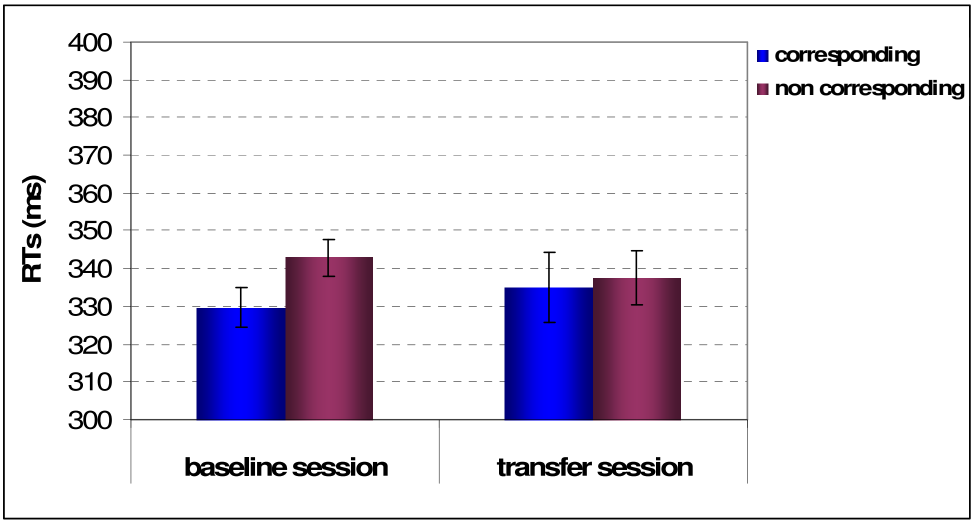


Figure 6.3 Study 3, Experiment 7: reaction times (ms) for the baseline and transfer sessions as a function of *stimulus–response Correspondence*. Error bars show standard errors of the means.

6.3.3 Discussion

The results of the Experiment 7 allow us to conclude that after a competitive practice task the joint Simon effect emerged in the baseline session disappears. Hence, a competitive training performed jointly with another person seems to influence the performance on a subsequent Simon task.

6.4 Experiment 8

Experiment 8 was aimed at assessing the duration of the practice effect. More specifically, we would evaluate whether the competitive practice used in Experiment 7 modulates the joint Simon performance even when in the transfer session participants experienced the opposite condition. To this end, in the first session participants were required to perform a joint Simon task in a neutral condition, than to carry out a practice with a competitive joint Flanker task, and in the third session to complete a joint Simon task in a cooperative condition. This procedure can allow us to understand whether a competitive practice can only produce a short-lasting effect (i.e., whether a significant joint Simon effect emerges when participants are placed in a cooperative condition after a competitive practice) or whether a competitive practice can have a long-lasting effect on the participants' performance (i.e., whether the joint Simon effect does not emerge even when participants experience a cooperative condition after a competitive practice).

6.4.1 Methods

6.4.1.1 Participants

Sixteen new undergraduates students from the University of Modena and Reggio Emilia (3 males and 13 females) with a mean age of 22.3 years (age range: 20–27 years) took part in the Experiment 8 for course credits. All subjects were right-handed and reported normal or corrected-to-normal vision. All were naive as to the purpose of the experiment and gave written informed consent. Once recruited, they were randomly paired.

6.4.1.2 Apparatus, stimuli, and procedure

Apparatus, stimuli, and procedure were the same as Experiment 7 except for the following.

During the transfer session participants performed a joint Simon task in a cooperative condition instead of in a neutral one. More precisely, as in the Experiment 7, during the practice session participants performed a joint Flanker task in a competitive condition and they were told that the best performing participant, in terms of both speed and accuracy, would receive a five Euro reward. Instead, during the transfer session each couple of participants performed a joint Simon task in a cooperative condition, namely in competition against the other couples, and it was told that the best performing couple, in terms of both speed and accuracy, would receive a ten Euro reward (five Euro to each participant).

6.4.2 Results

Data were treated as in previous experiments. Error trials (1 % in the baseline session and 1 % in the transfer session) were excluded from further analyses. Correct RTs were submitted to a 2 x 2 repeated-measures ANOVA with *Session* (baseline vs. transfer) and *stimulus–response Correspondence* (corresponding vs. non-corresponding trials) as within-subjects factors. Fisher’s LSD post-hoc test was also conducted on significant interactions.

The main effects of *Session* [F (1, 15) = 14.32, MSe = 704, p < .01] and *Correspondence* [F (1, 15) = 16.47, MSe = 115, p < .01] were significant. Participants were faster in the transfer (M = 341 ms) than in the baseline (M = 366 ms) session, and in corresponding (*M* = 348 ms) than in non-corresponding (*M* = 359 ms) trials. Data are shown in Figure 6.4. As indicated by the lack of a significant interaction between the two factors [*F* (1, 15) = 3.07, *MSe* = 22, *p* = 0.10], the advantage for corresponding responses was evident in both sessions, with a 13-ms joint Simon effect in the baseline session and a 9-ms effect in the transfer session. Even though the effect was numerically smaller in the third session than in the first one, this difference did not reach statistical significance.

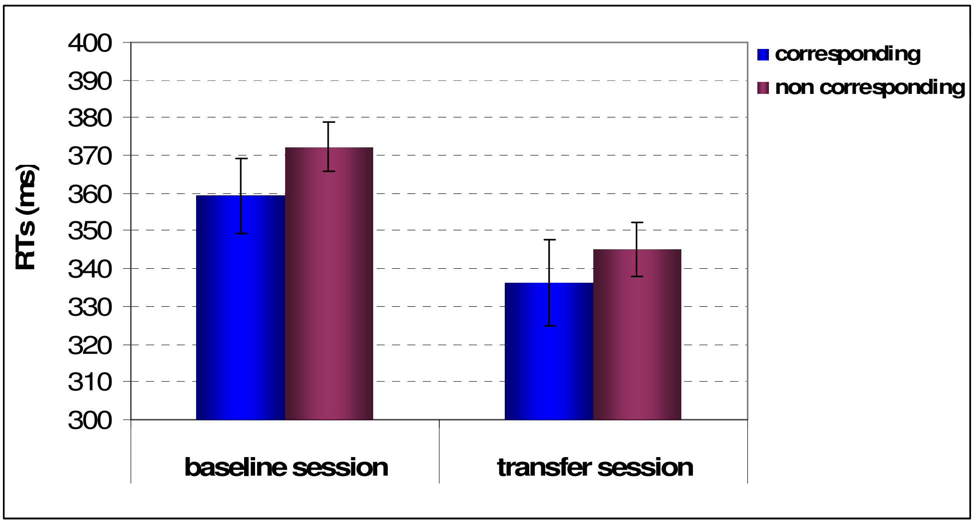


Figure 6.4 Study 3, Experiment 8: reaction times (ms) for the baseline and transfer sessions as a function of *stimulus–response Correspondence*. Error bars show standard errors of the means.

6.4.3 Discussion

The results of the Experiment 8 showed that a significant joint Simon effect emerged when participants were placed in a cooperative condition after a competitive practice, thus indicating that a competitive practice produced a short-lasting effect. Indeed, while in the Experiment 7 we showed that a competitive practice influenced the performance on a subsequent task with neutral instruction (i.e., the joint Simon effect was null), in the present experiment we demonstrated that a competitive training has not influence on a subsequent task with cooperative instruction (i.e., the joint Simon effect was present).

6.5 Comparison between Experiments 6, 7, and 8

To compare the magnitude of the Simon effect in the different experiments, the correct RTs of Experiment 6, Experiment 7, and Experiment 8 were entered into an ANOVA, with *Session* (baseline vs. transfer) as within-subjects factor and *Experiment* (6, 7, and 8) as between-subjects factor.

The main effects of *Session* [*F* (1, 45) = 13.99, *MSe* = 55, *p* < .001] was significant, showing that the joint Simon effect was significantly higher in the baseline session (*M* = 13 ms) than in the transfer (*M* = 8 ms) session. Both the effect of *Experiment* [*F* (2, 45) = 0.57, *MSe* = 387, *p* = 0.57] and the the interaction between *Session* and *Experiment* [*F* (2, 15) = 3.01, *MSe* = 55, *p* = 0.06] did not reach significance (Figure 6.5).

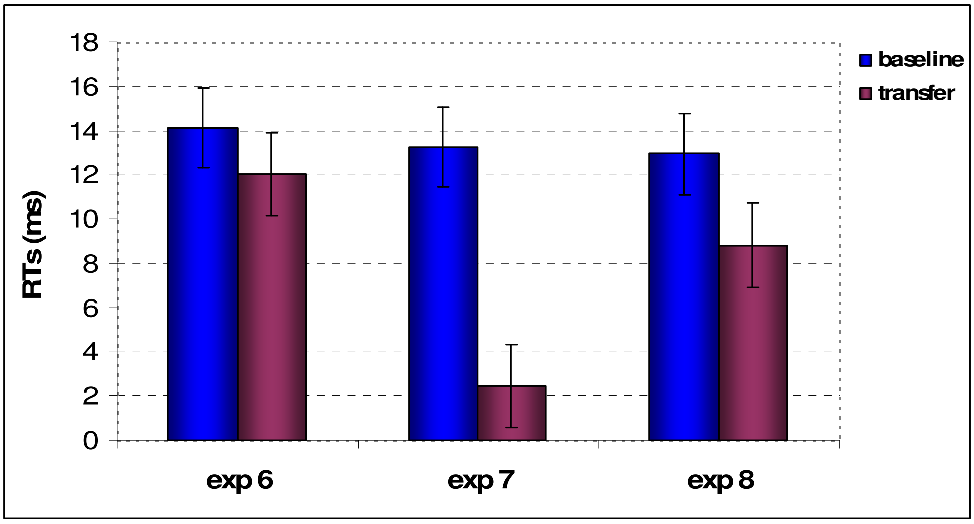


Figure 6.5 Study 3, Comparison Experiments 6, 7, and 8: reaction times (ms) for joint Simon effect as a function of *Session* (baseline and transfer) and *Experiment*. Error bars show standard errors of the means.

6.6 General Discussion

As previously stated (see Chapter 4), there is growing evidence suggesting that successful joint action depends, at least in part, on the ability to automatically share representations (Tomasello et al., 2005; Knoblich & Sebanz, 2006). However, the view that shared representations are automatically created any time individuals act in a social context has been put in question by researches that demonstrate the influence of social factors on the emergence of such representations, as indexed by the joint Simon effect. The results of the Study 2, presented in the previous chapter, seem to be in line with this latter statement, as they showed that shared representations were not activated when an ingroup–outgroup distinction is created by means of negative interdependence and thus co-acting individuals compete one against the other (Experiment 5).

The present study was aimed to extend our knowledge on the cognitive mechanisms at the basis of shared representations in collaborative and competitive contexts, by focusing on whether and to what extent prior experience could modulate performance in task sharing. Using behavioural measures and combining two experimental paradigms, namely the joint Simon and the joint transfer-of-learning, it has been possible to test whether and what kind of prior practice modulates performance. To address this question, we assessed whether joint action, as indexed by the joint Simon effect, can be specifically influenced by different kinds of previous experienced cooperative and competitive interdependence (Anelli et al., in preparation a).

Our results demonstrate that the joint Simon effect was present after a non-spatial cooperative practice, namely a cooperative training performed jointly with another person did not modulate the performance on a subsequent Simon task. Thus, the emergence of shared representations was evident when participants were prior required to cooperate to achieve a common goal and their performance was positively interdependent (Experiment 6). On the contrary, the joint Simon effect disappeared after a non-spatial competitive practice, namely a competitive training performed jointly with another person influenced the performance on a subsequent task, even if in this task participants received the explicit information that they are no longer in competition one against the other. Thus, shared representations were not activated when co-acting individuals were prior required to compete one against the other and their performance was negatively interdependent

(Experiment 7). Taken together, these findings confirm the modulation of the perceived interdependence on shared representations, since they emerged with positive and cooperative interdependence while they were disrupted by negative and competitive interdependence. It should be noticed that the specificity of the reported effect demonstrates the transfer of the specific type of relationship and of the specific instruction, and not the influence of any practice experienced jointly by two participants. Moreover, we can also rule out the influence on the performance in the transfer task of any spatial characteristics of the practice task, as it might happens with a spatial S–R correspondence task, since we chose a non-spatial practice task. These data are in line both with results of the Study 2 (Iani et al., 2011; Anelli et al., in press a) and with evidence derived from social psychology (Rabbie & Horwitz, 1969) reported in Chapter 5.

The novelty of this study consists in demonstrating the emergence of a "carry-over effect of competition", of which there is evidence in social psychology (Sassenberg et al., 2007), by combining two paradigms of cognitive psychology such as the joint Simon (Sebanz et al. 2003) and the joint transfer-of-learning (Milanese et al., 2010). More specifically, by means of this innovative methodology we demonstrated the influence of this carry-over effect of competition on the emergence of shared representations. Instead, social psychology studies have shown that this effect well explains the increase in levels of prejudice towards an unrelated outgroup not involved in competition, after both the imagination or recollection of a competition from memory and the participation in a competition (Sassenberg et al., 2007). Notably, in our case the competition concerns two participants and not groups.

Another relevant point of the present work is that, by using the joint Simon and the joint transfer-of-learning paradigms, we have investigated another aspect of this carry-over effect of competition, namely its duration (Experiment 8). To the best of our knowledge, this element has never been measured before in the topic of joint action. Specifically, we wanted to explore whether, once established a competitive setting, the joint Simon effect did not emerge even though participants receive new instructions and experience a cooperative interaction, thus demonstrating that it was a long-lasting effect, or whether a competitive practice can only produce a short-lasting effect. Our results allow us to claim that the carry-over effect of competition has a short-lasting effect, since it is canceled when the same participants experienced a cooperative and positive interaction. This finding is consistent with a theory presented above, namely the realistic group-conflict theory (Sherif, 1966; Sherif & Sherif, 1969), which argues that competition between two groups decrease only when intergroup cooperation is required to achieve a common goal. However, it must be noted that in our case there is a competition between two persons and not between two groups. Despite this difference, what should be emphasized is that the introduction of a common goal for both participants decreases competition in our study, leading to a cancellation of the carry-over effect of competition. This result can be well explained as follows: attitudes toward outgroup (or toward another participant, as in our case) are a reflection of the structural relationship between ingroup (self in our case) and outgroup (other participant in our case) goals or interest. In line with this explanation, evidence from social psychology studies showed that negative attitudes, intergroup hostility, low level of support, stereotypes, and prejudices emerge when there is a negative interdependence and the aims are incompatible (Sassenberg et al., 2007; for a review, see Riek et al., 2006).

Our findings deserve a last consideration. The short-lasting carry-over effect of competition is also consistent with some conclusions and same references mentioned during the discussion of the Study 2. Namely, according to Tomasello et al. (2005) we can argue that individuals tend for their nature to share goals and intentions, and to cooperate with others, and according to Poortvliet and Darnon (2010) that positive interdependence can increase the individuals’ intention to invest in the interaction, allowing the emergence of shared representations. This intention is weakened in the case of competitive situations.

To conclude, the present study confirms that shared representations do not automatically emerge every time individuals act in a social context, and that the tendency to integrate the others’ action into our own action system and to cooperate is quite strong.

GENERAL CONCLUSIONS

The present project has been conducted within the Social Cognition framework. The perspective of the thesis can be inscribed in the area of cognitive science that is undergoing an important shift, from the focus on the human abilities of individuals acting in isolation to the investigation of aspects of social understanding (Chapter 1). A crucial point is the idea that action observation can support the understanding of goals and intentions, as claimed by different theories, namely the common coding theory (e.g., Prinz, 1997), the motor simulation theory (e.g., Jeannerod, 2003), and the motor resonance theory (e.g., Rizzolatti & Craighero, 2004). Among the several topics of social cognition, my doctoral thesis was focused on motor resonance and joint action. These issues have been separately treated in the first (Chapter 2) and in the second (Chapter 4) part of the thesis, respectively, starting from a theoretical and empirical analysis to the experimental investigation in a series of experiments, conducted by using two effects of cognitive psychology, namely the affordance and Simon effects.

The motor resonance topic has been investigated with the affordance effect in the Study 1 (Chapter 3; Anelli et al., in press b; Anelli et al., under review). In particular, two questions have been addressed in three experiments with a priming paradigm on adults and school-age children: first, how motor responses to objects and sensitivity to fine object characteristics (i.e. object typology and object category) develop, and second how motor resonance develops.

As far as first point is concerned, I explored both the ability to differently perceive and process objects that can be potentially source of danger or pain for us (dangerous object) and objects that we can approach and interact without any risk (neutral object), and the ability to discriminate between artefact and natural objects. Results clearly demonstrate that both children and adults, males and females, are sensitive to the difference between dangerous and neutral objects, since response times were slower with the first than with the second. This finding could be interpreted as due to two mechanisms, an interference or a blocking mechanism, that however the present data cannot disentangle. Indeed, it is possible that even dangerous objects evoke affordances, as neutral ones, but that responses to them are slowed down due to the presence of a late occurring blocking mechanism. Alternatively, it is possible that dangerous objects, even if they are potentially graspable, do not elicit reaching or grasping actions toward the object, but that they rather evoke aversive affordances, due to the perception of their danger from very early processing phases. It can be proposed that only data on time course could allow us to clarify to what the delay with dangerous objects is due and whether affordances or aversive affordances are activated. However, some speculations are possible concerning the different underlying neural mechanisms. The slowdown of responses can be associated to an inhibition effect provoked by a selective attention mechanism or can be due to the threatening character of the stimuli (e.g., Algom et al., 2004). Another possible way to understand the mechanism underlying the slowing of response times with dangerous stimuli compared to neutral ones is in terms of the mechanisms responsible for treating cognitive conflict. Considering the TRoPICAL model proposed by Caligiore and colleagues (2010, 2012), the prefrontal cortex (PFC) plays a double role, exerting both an inhibitory and an excitatory control. Since PFC can receive inputs from the emotional circuits, in the current study it may allow participants to inhibit the tendency to respond to affordances in case of dangerous objects. Alternatively, two different, separable circuits underlie cognitive and emotional conflict (e.g., Etkin et al., 2006; Egner et al., 2008): a lateral PFC system devoted to resolving conflict non related to emotional stimuli, and a rostral anterior cingulate system devoted to resolving emotional conflict and associated with a top-down inhibition of the amygdala with emotional distractors. However, PFC would have also an impact on inhibition related emotional stimuli (Munakata et al., 2011).

Concerning the ability to discriminate between artefact and natural objects, a specific developmental trajectory emerged, since sensitivity to the difference between objects categories starts to develop in children but appears clearly only in the adult-female group, since response times were faster with natural objects than with artefacts. Thus, even if the task requires to distinguish between artefacts and natural objects, at all ages participants respond differently to dangerous and neutral objects, but more fine-grained differences such as those related to object category emerge later. This result is in line with the literature (Borghi et al., 2007; Vainio et al., 2008; Anelli et al., 2010) and could be due to the activation of both manipulative and functional information with artefacts, and only of manipulative information with natural objects. This study adds to previous results in the literature as it shows that participants respond differently to the two object typologies only when they dealt with neutral objects, while with dangerous objects the perception of their danger overcame more fine-grained categorical distinction. It remains to be explained why females responded differently to natural objects and artefacts, while males did not.

As far as second point is concerned, in order to investigated how motor resonance develops, I explored whether both children and adults were sensitive to the affordances and the potential dangers offered by the objects in the environment to others, and whether a general resonance or a more fine-grained motor resonance phenomenon occurred. Results show an effect of primes that can reflect the existence of a resonant mechanism. Such mechanism seems to be already developed in children, but it could become more fine-tuned with age. Indeed, children already resonate more to the biological (human hands) than to the non-biological (robot hand and brick) primes. This effect can be due to a higher motor resonance when the hand is similar to our own. To note, while a higher general resonance with biological than with non-biological stimuli is already present in children, they do not respond to gender differences of the hand primes. Results reveal that adults become more sensitive to fine-grained aspects of the biological stimuli, since male participants respond faster to grasping hands of their own gender, thus showing that they are aware of gender and postural differences in biological hands. Further investigation are necessary to clarify why the gender-dependent motor resonance and the ability to distinguish between a static and a grasping posture are not present with women. For example, these findings could be due to an effect of gender stereotyping, leading to respond fast to man's hand, or to the higher attention women pay to objects characteristics instead than to action characteristics, so explaining the females more fine-grained categorical distinction above reported. Some hypotheses are possible concerning the different underlying neural mechanisms. Facilitation with prime stimuli that might produce resonance and interference with dangerous compared to neutral object indicate that observing a hand in a given posture induces participants to prepare an action, probably through the mediation of the mirror neurons. This action is prepared faster when the hand we observe is rather similar to our own. Such resonant effects is in line with the ideomotor theories (Prinz, 1997; Hommel et al., 2001), according to which perceived events and actions rely on the same representational code. For this reason, the more similar are the observed action and the performed action, the more motor responses would be facilitated. Once the motor response is prepared, however, it has to be adapted to a specific object. The absence of an interaction between prime and objects suggests that two different neural systems can be involved in an independent way: one activated by the action observation and possibly mediated by the mirror neurons, the other activated by the object observation and possibly mediated by the canonical neurons (Rizzolatti & Craighero, 2004). The absence of this integration could be due to the priming paradigm used, since in a recent study by Morrison et al. (2012), there is evidence of integration between action and object information. In particular, they showed that viewing grasping actions toward dangerous objects activates the post-central sensorimotor cortex that integrates both object and action information in order to process the sensory outcomes of observed hand-object interaction.

Overall, this study is the first that investigates how sensitivity to dangerous and neutral objects develops and the effects that these different objects can have on other organisms, and it provides the first evidence of resonant mechanism while interacting with dangerous objects. These represent the really original contributions of this research.

The second main issue of this dissertation concerned joint action and has been investigated with the Simon effect both in the Study 2 and in the Study 3, starting from some findings which indicate the influence of social factors on the processes underlying joint actions and shared representation.

Specifically the Study 2 (Chapter 5; Iani et al., 2011; Anelli et al., in press a) assessed whether shared representations, as indexed by the presence of the joint Simon effect, are modulated by group membership. In particular, the Experiment 4 investigated the role of minimal ingroup–outgroup distinctions. I used a social psychology paradigm proposed by Tajfel et al. (1971), the minimal cues manipulation, and participants were arbitrarily divided in two groups, to measure their performance when a joint Simon task was executed by two individuals who belong to the same group or to a different group. Results clearly show that shared representations emerge even when participants believe to perform the task along with a member of a different group. The lack of difference in performance of participants belonging to two different categories suggests that a simple self-categorization condition is not sufficient to activate different strategies of interaction, on the basis of the sharing or not of the same categorical label with the partner during the joint Simon task, namely on the basis of perceiving themselves as part of the same or of a different group as a co-actor.

Instead, in Experiment 5 a more complex ingroup–outgroup distinctions was employed. I started from the propose of Rabbie and Horwitz (1969) that a perceived positive interdependence is the precondition for group formation and for subsequent ingroup–outgroup differentiation, and I manipulated the role of experienced interdependence between participants. Participants' performance in a joint task was measured when the goals of two jointly acting individuals were positively related and thus they had to cooperate, and when the goals were negatively related and thus individuals had to compete during the task. Results reveal that the activation of shared representations occurs only when individuals cooperate but not when they compete, thus demonstrating that joint actions are influenced by the type of interdependence between co-actors.

Taken together, findings of Study 2 may contribute to a long-lasting debate on social psychology, between authors as Tajfel (1970) who claimed that social categorization is a sufficient antecedent of ingroup–outgroup distinction and of consequent ingroup-favoring discrimination, and others authors as Rabbie and Horwitz (1969) who raised questions about whether social categorization alone is sufficient for group formation and intergroup discrimination. These results, showing that only the ingroup–outgroup distinction produced by negative interdependence is strong enough to disrupt the emergence of shared representations, favors the view that ingroup–outgroup discrimination processes are enhanced by perceived interdependence, according to Rabbie and Horwitz position. Even though these findings are at odd with the view that shared representations emerge automatically any time individuals act together in a social context, they suggest that the tendency to integrate the co-actor's action into our own action system is quite strong, in line with literature (e.g., Sebanz et al., 2003; Tsai et al., 2008). Indeed, the emergence of a joint Simon effect under both same group and different group conditions of Experiment 4, and the observation that it is of comparable magnitude under these two conditions and under the cooperative condition of Experiment 5 suggest that when acting in a social context, by default, individuals may perceive positive interdependence with co-acting individuals, even when cooperation is not explicitly requested.

Overall, the original contribution of this research consists in merging evidence and paradigms both of social and cognitive psychology to demonstrate the influence of social factors on the processes underlying joint actions and shared representation.

The Study 3 (Chapter 6; Anelli et al., in preparation a) was strictly related to the previous investigation, as it was aimed at extending knowledge on the cognitive mechanisms at the basis of shared representations. More precisely, it was further assessed whether shared representations are modulated by group membership, in particular by the interdependence experienced by two individuals, combining two paradigms of cognitive psychology, the joint Simon and the joint transfer-of-learning. In particular, first of all the research investigated whether performing a cooperative (Experiment 6) or a competitive (Experiment 7) joint practice task influences the way a subsequent task is executed. To this aim, participants' performance was measured and compared before and after the introduction of a condition of interdependence. Results demonstrate the emergence of shared representations when participants were prior required to cooperate to achieve a common goal and their performance was positively interdependent (Experiment 6), whereas shared representations are not activated when participants were prior required to compete one against the other and their performance was negatively interdependent (Experiment 7). On the whole, these data confirm the modulation of the perceived interdependence on shared representations. The specificity of the reported effect which emerges only in the competitive condition, and thus it can be defined as a carry-over effect of competition, demonstrates the transfer of the specific type of relationship and of the specific instruction. This allow to exclude that the effect can be due to the influence of any practice experienced jointly by two participants or to spatial characteristics of the practice task, since a non-spatial practice task was chosen. These data are in line both with results of Study 2 (Iani et al., 2011; Anelli et al., in press a) and with evidence derived from social psychology (Rabbie & Horwitz, 1969).

As second relevant point, the Study 3 investigated the duration of the carry-over effect of competition (Experiment 8). Specifically, I explored whether a competitive practice can produce a long-lasting or a short-lasting effect. Results allow to claim that the carry-over effect of competition has a short-lasting, since it is canceled and leads to the emergence of shared representation when the same participants experience a cooperative and positive interaction after a competitive practice.

On the whole, the original contribution of Study 3 is the demonstration of the influence of this carry-over effect of competition on the emergence of shared representation, to date an effect only reported in social psychology researches to explain the increase in levels of prejudice towards an unrelated outgroup, after both the imagination or recollection of a competition from memory and the real participation in a competition (Sassenberg et al., 2007). Moreover, the short duration of the carry-over effect of competition is consistent with the realistic group-conflict theory (e.g., Sherif & Sherif, 1969) which argues that competition between two groups decrease when intergroup cooperation is required to achieve a common goal.

Taken together, findings of Study 2 and of Study 3 demonstrate that shared representations do not automatically emerge every time individuals act in a social context, but that the tendency to integrate the others' action into our own action system and to cooperate is quite strong, as co-representations emerge even when cooperation is not explicitly requested and as soon as a cooperation becomes necessary to attain a common goal. This result is consistent with Tomasello and colleagues (2005) who argue that human beings are inclined to share goals and intentions. The authors analyzed what makes human cognition so unique in the animal kingdom, by creating the possibility of culture and cultural evolution. They claimed that what makes the difference is not language nor theory of mind nor difference in sociality between humans and other animals, but the adaptation for participating in collaborative activities involving shared intentionality. This fundamental human ability requires selection during human evolution process both for skills of others' intentions reading and for motivation to share intentions and cooperate with others. Finally, as claimed by Poortvliet and Darnon (2010) the perception of positive interdependence situation may enhance the willingness to invest in the interaction, thus facilitating the emergence of shared representations, whereas in competitive situations individuals may be blocked in integrating self and other's action due to their less willingness to coordinate their efforts, to depend on, and to be influenced by the other's actions.

To conclude, several experimental evidence has been reported in this doctoral thesis concerning both motor resonance and join action. These results widely extend previous ones reviewed in my work, as they show resonant mechanisms when interacting with dangerous objects (Study 1) and modulation of social factors on the emergence of shared representation during joint actions (Studies 2 and 3). Certainly, further researches are necessary in order to investigate in deep these complex issues and to better understand the neural mechanisms underlying these behavioral effects. On the whole, the original contribution of these studies is represented by the application of cognitive psychology methodologies in the investigation of relevant topics within the Social Cognition research.

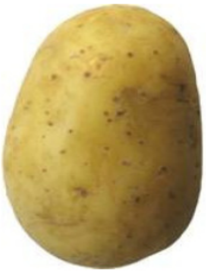
APPENDICES

Appendix A. Study-sample: experimental stimuli, 24 objects.

	HARD OBJECTS	**SOFT OBJECTS**
ARTEFACT OBJECTS	Bottle 	Bathroom tissue 
	Flowerpot 	Doughnut 
	Glass 	Hat 

	Mug 	Puppet 
	Perfume bottle 	Sponge 
	Receiver 	Woolen ball 
NATURAL OBJECTS	Carrot 	Chicory 

Cob 	Fig 
Coconut 	Lettuce 
Cucumber 	Mushroom 
Melon 	Persimmon 

	Potato	Tomato
		

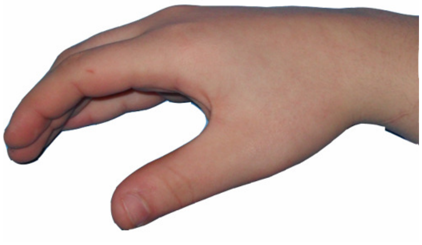
Appendix B. Study 1: experimental stimuli.

B.1 Experiment 1, 2, and 3: 16 objects.

	NEUTRAL OBJECTS	**DANGEROUS OBJECTS**
ARTEFACT OBJECTS	Bulb 	Broken bulb 
	Glass 	Broken glass 
	Lighted out match 	Lighted match 
	Spoon 	Knife 

NATURAL OBJECTS	Cat 	Scorpion 
	Chick 	Husk 
	Plant 	Porcupine 
	Tomato 	Cactus 

B.2 Experiment 1: 6 primes.

Grasping hand of a female child 	Grasping hand of a male child 
Static hand of a female child 	Static hand of a male child 
Grasping hand of a robot 	Control stimulus (brick) 

B.3 Experiments 2 and 3: 6 primes.

Grasping hand of a female adult

Grasping hand of a male adult

Static hand of a female adult

Static hand of a male adult

Grasping hand of a robot

Control stimulus (brick)

Appendix C. Study 2: first cognitive task.

BETULLA

GATTO

PINZA

MARTELLO

TARTARUGA

PINO

SALICE

CANE

IPPOCASTANO

ACCETTA

CONIGLIO

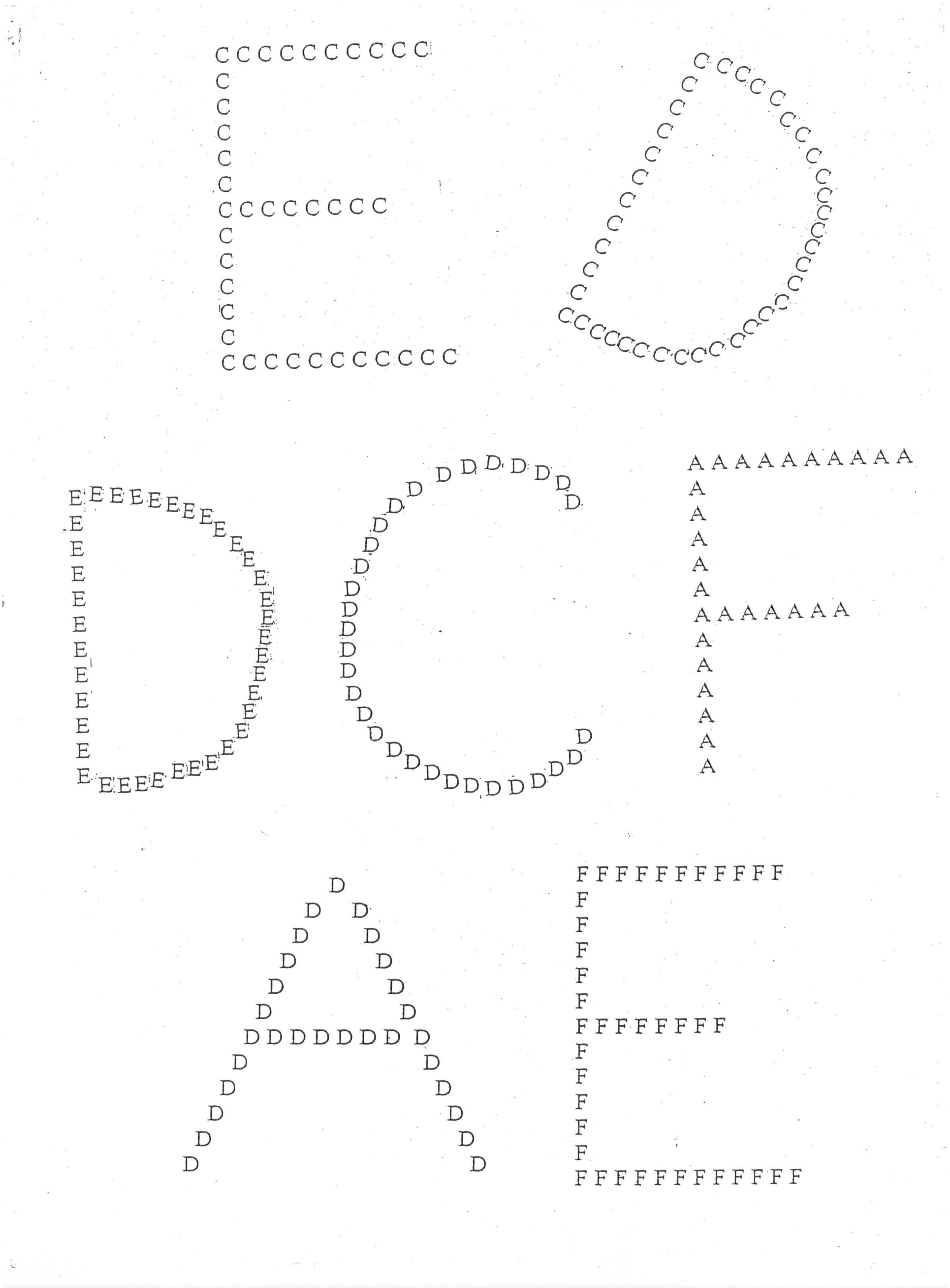
BADILE

FORBICI

CIPRESSO

MUCCA

Appendix D. Study 2: second cognitive task.



Appendix E. Study 2: post-experiment questionnaire.

Conoscevo già il mio compagno:

☐ **sì**

☐ **no**

Se sì, qual è il grado di conoscenza:

☐ l'ho visto una volta

☐ l'ho visto alcune volte

☐ lo vedo sempre

☐ siamo compagni di corso

☐ siamo amici

La situazione è stata:

Facile	☐ ☐ ☐ ☐ ☐ ☐ ☐	Difficile
Piacevole	☐ ☐ ☐ ☐ ☐ ☐ ☐	Spiacevole
Positiva	☐ ☐ ☐ ☐ ☐ ☐ ☐	Negativa
Competitiva	☐ ☐ ☐ ☐ ☐ ☐ ☐	Non competitiva

La mia prestazione è stata molto simile a quella del mio compagno:

Completamente d'accordo ☐ ☐ ☐ ☐ ☐ ☐ ☐ Completamente in disaccordo

Se sei in disaccordo, scegli una delle seguenti opzioni:

☐ la mia prestazione è stata migliore

☐ la sua prestazione è stata migliore

Appendix F. Study 3: joint Flanker task stimuli.

	STIMULUS TYPES			
TARGETS	**Identical**	**Compatible**	**Incompatible**	**Neutral**
H	HHHHH (Hid)	KKHKK (Hcomp)	SSHSS (Hinc)	UUHUU (Hneu)
K	KKKKK (Kid)	HHKHH (Kcomp)	CCKCC (Kinc)	UUKUU (Kneu)
S	SSSSS (Sid)	CCSCC (Scomp)	KKSKK (Sinc)	UUSUU (Sneu)
C	CCCCC (Cid)	SSCSS (Ccomp)	HHCHH (Cinc)	UUCUU (Cneu)

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