Impact of children's Theory of Mind on their social interaction and cognitive performance in cooperative problem-solving tasks

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Karine Porpino Viana

Abstract

Research on Theory of Mind (ToM) has produced substantial knowledge about the development of children's ability to understand cognitive and emotional mental states and processes in the self and others. Research shows that social interactions boost ToM development in preschool years, as children are encouraged to consider others' thoughts and feelings while interacting in order to plan actions and adjust their own behaviours, feelings and thoughts to those of others. The reverse relationship, i.e., the impact of children's ToM on their social interactions, has been less examined and the findings are scarce and unclear, particularly, with regard to the impact of children's ToM on the way they interact with other children and their cognitive performance in cooperative problem-solving situations. The understanding of whether children's understanding about their own and others' minds (*ToM as declarative knowledge*) matter for how they apply this knowledge in cooperative problem-solving contexts (*ToM as a procedural skill*) is therefore limited.

The main aim of this thesis was to examine to what extent children's ToM (i.e., cognitive and emotional aspects) impacts their performance and the way they interact in cooperative problem-solving tasks. Sixty-eight children between 4 and 9 years of age were assessed for their ToM, cognitive performance and social interactions in both individual and cooperative conditions of a spatial transformation task and a sensorimotor task.

In Paper I, we examined to what extent ToM – including the understanding of both cognitive and emotional states – explains children's performance in a cooperative spatial transformation task. Results showed that children performed better when they resolved it with a partner, and that children's ToM was a better predictor of their performance in the cooperative condition than their age, gender and performance in the individual condition. These findings suggest that ToM might be an important mechanism underlying cognitive performance in a cooperative spatial task.

In Paper II, we investigated the impact of Emotion Understanding (EU) on children's performance in a cooperative sensorimotor task. The results showed that EU was positively associated with the performance in the cooperative condition but not with the performance in the individual condition. Moreover, higher EU significantly explained greater performance in the cooperative sensorimotor task, even when controlling for age, gender and the child's performance in the individual

condition. These findings build on the first paper by also pointing to the significance of emotional mechanism underlying successful coordination of actions in peer interaction, shedding light on the links between motion and emotion.

In Paper III, we addressed the question of whether ToM – including the understanding of both cognitive and emotional states – impacts children's attitudes toward another's perspective in a cooperative spatial task, and to what extent it affects their task performance. Results showed that children with lower ToM tended to reject the other's perspective, whereas children with higher ToM more frequently took into consideration the other's perspective when faced with conflicting ideas. Moreover, lower ToM scores and greater rejection attitude also accounted for poorer performance in the cooperative condition of the task. The results are discussed in terms of the socio-cognitive mechanism underlying peer cooperation and in particular how the relationship between ToM as a declarative knowledge and ToM as a procedural skill can be apparent in early childhood.

Taken altogether, the findings of this thesis suggest that ToM is a socio-cognitive mechanism underlying cooperation by informing on the role of ToM for the way children interact and for their performance in problem-solving tasks. The results, thus, advance our understanding of the potential links between ToM as declarative knowledge and ToM as a procedural skill. Knowledge about when children develop an understanding of their own and others' minds and when they develop the ability to apply this knowledge can have implications across social learning contexts, including school settings.

List of Papers

Paper I

Viana, K.M.P, Zambrana, I.M, Karevold, E.B., Pons, F. (2016). Beyond conceptual knowledge: The impact of children's theory-of-mind on dyadic spatial task. *Frontiers in Psychology, 7*, 1-11. doi: 10.3389/fpsyg.2016.01635

Paper II

Viana, K.M.P, Zambrana, I.M, Karevold, E.B., Pons, F. (2018). Emotions in motion: impact of emotion understanding on children's peer action coordination in a sensorimotor task. *Submitted to Cognition and Emotion.*

Paper III

Viana, K.M.P, Zambrana, I.M, Karevold, E.B., Pons, F. (2018) "Are we both right?" Theory of mind explains perspective taking in a cooperative problem-solving spatial task. *Submitted to International Journal of Behavioral Development*

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1 Introduction

"And so I cry sometimes when I'm lying in bed just to get it all out what's in my head…And I am feeling a little peculiar…"
4Non Blonds – What's up

This is the song spinning around in the head of eight strangers from different parts of the world who feel very peculiar and confused after they had suddenly become "sensates", a different species of human beings, called *homo sensorium*. The eight individuals compose a cluster, a group in which the members are intellectually and emotionally connected; and this connection allows them to share their feelings, moods, knowledge, language and skills in a peculiar way by literally visiting the others' minds and bodies. This science fiction story of a Netflix series called *Sense8* created by the Wachowski sisters – the creators of *Matrix* – takes us to a world where people can directly access others thoughts and feelings, and, consequently, perform one another's actions. Are they really peculiar types of human beings? To what extent is this narrative a fiction or a scientific fact? To what degree can one access other's minds and know what others think and feel? Imagine now a very common interaction between two children: Child A approaches child B, who is playing with some toys. Before child A touches or says anything, child B warns: "I will not give you any of these toys". In this example, one can say that Child B had some beliefs about the intentions or desires of child A (e.g., "she must be coming closer because she wants to grab some of my toys"). Maybe the belief about the intentions and desires of child A was false and child A simply intended to sit down; or maybe child B was accurate in the prediction of child A's behavior. It is almost impossible to conceive of an interaction free of the endeavor of trying to understand oneself and others as mental agents. Yet, different from the "sensates", we cannot (at least so far) be completely sure about other's thoughts and feelings. As Wellman (2014, p. 3) said, "no one can step inside someone else's mind and know it. So every mind we sense, interact with, and attribute to others is, by necessity, a mind we make". In other words, we can have some theories about other's minds but we cannot actually be inside the other's mental and emotional worlds. Perhaps the "sensates" artistically illustrate an extraordinary use of theory of mind abilities; indeed, in this fictional narrative the most clear and positive result of being able to visit other's minds is that individuals within a cluster can reach a high level of cooperation by successfully coordinating their thoughts, feelings and bodies. *"I am not just a me, but I am also a we"* is one of the main take-home messages of the series. However, in the scientific field, we still have many unanswered questions about how children's ability to think about others as mental agents changes both the way they interact with others and their performance in problem-solving situations. This is what this thesis is about.

Research on Theory of Mind (ToM) has produced considerable knowledge about the nature, development and origins of children's ability to explain, predict and change cognitive and emotional mental states and processes in the self and others (e.g., Pons & Harris, in press; Wellman, 2014 for reviews). This line of work has furthermore provided substantial evidence for the crucial role of social interaction for children's ToM development (e.g., Carpendale & Lewis, 2004; Wellman, 2018). Nevertheless, the reverse relationship, i.e., whether ToM brings about positive implications for children's social interaction has been less examined (e.g. Grüneisen, Wyman, & Tomasello, 2015; Harris, 2006; Pons, Harris, & Doudin, 2002 for reviews). Recent studies have shown that children's ToM is positively associated with their overall prosocial behaviors and social competences (e.g., Barreto, Osório, Baptista, Fearon, & Martins, 2018; Caputi, Lecce, Pagnin, & Banerjee, 2012; Farina & Belacchi, 2014; Roazzi et al., 2013). However, the implications of ToM for the way children interact during cooperative problem-solving tasks and the cognitive outcome of these interactions have received little attention. This is an important issue to be addressed because children typically spend a significant amount of their time interacting with other children, and they are frequently exposed to situations demanding cooperative problem-solving skills, particularly in school settings. Although working on a joint goal seems to intrinsically demand ToM abilities, as children have to coordinate behaviors and distinct points of view in order to jointly conclude a given task, the findings are mixed regarding the degree to which ToM impacts peer interaction (Guajardo & Cartwright, 2016; Veneziano, Albert, & Martin, 2008). Overall, the current literature still has some gaps with regard to our understanding of whether children's understanding about their own and others' minds (*ToM as declarative knowledge*) matter for how they apply this knowledge in cooperative problem-solving contexts (*ToM as procedural skill*).

The main aim of this Ph.D. thesis was therefore to investigate to what extent ToM can explain: 1) children's performance in a cooperative spatial transformation task; 2) children's performance in a cooperative sensorimotor task; and 3) children's attitude toward the perspective of a peer in a cooperative spatial transformation task.

The results from the studies presented in this thesis advance our knowledge about: 1) the role of ToM for cognitive performance in cooperative problem-solving situation; 2) ToM as one of the mechanisms underlying cooperative activities; 3) the relation between having ToM (declarative knowledge) and using ToM abilities (procedural skill); and 4) the potential educational implications of these findings for school settings.

2 Social cognition: understanding the mental world

2.1 What is Theory of Mind?

Social cognition generally refers to reflective processes related to others' mental worlds (De Jaegher, Di Paolo, & Gallagher, 2010), consequently involving reasoning about people's mental states (Astington & Hughes, 2013). The issue about how humans can understand their own and others' mind has a long history in philosophy and psychology (Wellman, 2017), and very early in developmental psychology a vivid debate around the nature of social cognition emerged. It is recognized that this debate originated with Jean Piaget (e.g., Flavell, 2000). The Piagetian view of the child as naturally egocentric presupposes that children at an early age are not able to acknowledge the existence of different perspectives or points of view. In the classical "Three Mountains" task, Piaget and Inhelder (1948; Meyer, 1935) asked children to imagine how a doll would view a mountain scene from several different positions, and they found that only from 9 years of age children were able to disengage from their own point of view and were aware of the others' perspective. The Piagetian approach prevailed into the 70's, but gradually studies with young infants also provided support for what could be referred to as the Vygotskyan hypothesis about the social child. According to this socio-constructivist approach, from an early age children can share and engage in mutual interaction (e.g., Meltzoff & Moore, 1977; Trevarthen & Hubley, 1978), showing some implicit understanding of their own and others' mental world. Therefore, a second wave of research flourished around the 1970s with the focus on metacognitive development, providing valuable studies on comprehension, perception, attention, and problem-solving (Flavell, 2000). At that time, although investigations on how children differentiate the self and the others had bloomed, the term "Theory-of-Mind" or "ToM" had not yet been applied. ToM studies can be seen as the third wave of research and has, according to Flavell (2000), since the 80s become one of the most active and productive research fields in developmental psychology.

The term "Theory of Mind" was originally introduced by a landmark paper of two primatologists Premarck and Woodruff (1978) where they reported a study conducted with chimpanzees aiming to investigate whether non-human primates infer the goals, desires, and plans underlying behaviors. They defined ToM as the ability to attribute mental states to others. They also justified the use of the word "theory" because: 1) it implies a system of inferences that cannot be directly observable; 2) and because it allows the prediction, explanation and manipulation of others' actions and representations. In the early 1980s two developmental psychologists Wimmer and Perner (1983) tested young children's understanding of false-belief in a pioneering study using the "unexpected transfer" paradigm. This task demanded understanding that when someone is ignorant about the location of an object, this makes the person behave according to his/her knowledge of the situation, even when this knowledge is based on a mistaken belief. This view led to an immense focus on children's performances on false-belief tasks, which became the most common way to assess the acquisition of ToM abilities (e.g., Baron-Cohen, Leslie, & Frith, 1985; Hogrefe, Wimmer, & Perner, 1986; Perner, Leekman, & Wimmer, 1987; Gopnik & Astington, 1988 for other ways to assess children's understanding of false-belief).

Meanwhile, other groups of research emerged and also became part of the ToM movement, conducting studies on the understanding of mental terms, on children's knowledge about perception and on the appearance-reality distinction (e.g., Flavell, Flavell, & Green, 1983; Flavell, Flavell, Green, & Wilcox, 1980). These earlier studies have contributed to research that either investigates children as little cognitive scientists (Flavell, 1979) or as little affective scientists (Harris, Olthof, & Terwogt, 1981). Thus, the term "Theory of Mind" has mostly been referred to the understanding in the strict sense of the cognitive side of the mind (i.e., beliefs, knowledge, perspectives, and intentions), whereas the term "Emotion Understanding" (EU) has been used to the comprehension of the affective side of the mind (e.g., Pons & Harris, in press). Although some variation in the ways in which ToM is defined, a relative consensus exists when it comes to the general conceptualization of the term. It can be understood as the ability to ascribe mental states to the self and others, as well as to theorize about others' mind by making inferences regarding mental phenomena, thereby enabling the prediction, explanation and manipulation of others' actions and representations (e.g., Harris, de Rosnay, & Pons, 2016; Wellman, 2018). As a consequence, ToM is strongly linked to self-reflection and social understanding (Astington & Hughes, 2013), allowing us, for instance, to distinguish thoughts from things, beliefs from actuality, desires from outcomes (Wellman, 1990). EU is the ability to understand the nature, causes and consequences of emotional experiences (e.g., Pons & Harris, in press). It has consequently been referred to as the declarative dimension of emotional competence and the affective side of ToM (Bender, Pons, Harris, Esbjørn, & Reinholdt-Dunne, 2015; Sprung, Münch, Harris, Ebesutani, & Hofmann, 2015). Its main function is to explain, predict and control emotional experiences in everyday life. As Pons and Harris (in press, p. 1) state, "Emotion Understanding is to emotion what Theory of Mind is to cognition; Emotion Understanding is cognition about emotion (whereas Theory of Mind is cognition about cognition)". In this integrative chapter we use the term ToM in its larger sense to refer to the ability to understand beliefs, perspectives, intentions, desires and emotions in the self and in others.

After more than 35 years of research on ToM, the issue about how humans understand the mental world continues to fascinate and intrigue many scholars in developmental psychology. Why is this topic still so popular? An understanding of the mind is crucial to be able to behave and live in a social world (Wellman, 1990), and despite the robust knowledge produced in the past years about how this ability develops, there are still many unanswered questions about the origins and real-world consequences of ToM acquisition (Astington, 2001; Wellman, 2018). In the past years, new directions of studies have flourished, exploring, for instance, neuro-mechanisms underlying ToM abilities (e.g., Gallagher & Frith, 2003; Schurz & Perner, 2015), infants' understanding of mental states (e.g., Moll & Tomasello, 2012; Repacholi, Meltzoff, Rowe, & Toub, 2014), and the social and cognitive consequences of acquiring ToM (e.g., Reschke, Walle, & Dukes, 2017; Surtees & Apperly, 2012). The present thesis is linked to this last topic. Thus, in order to make clear the relevance and originality of our research question, the next sections will cover reviews of: 1) how ToM develops; 2) What is ToM *for*; and 3) the relationship between procedural and declarative ToM in terms of developmental continuity versus discontinuity. We believe that the debate about continuity versus discontinuity between procedural ToM and declarative ToM is extremely relevant to the understanding of the relations between ToM and social interaction, which is the central feature of the studies presented in this thesis. Taking into account that our studies investigated typically developing school-age children, we will focus on presenting conceptual and empirical data predominantly related to this age range, and to developmental phases relevant to the core discussion of our findings. For the same reason, we will not explore ToM development in non-typical populations.

2.2 How does Theory of Mind develop?

One of the very fundamental discussions about the development of ToM relies on the degree to which children are born as "mentalist agents" (and perhaps share this competence with other animals), or whether this is a skill predominantly determined by the social environment (Wellman, 1990). Traditionally, there are three main approaches toward this question. The theory-theory view claims that ToM development in children is analogous to theory development in science, with the mental states concepts being reorganized when faced with counter-evidence to its predictions (Gopnik & Wellman, 1994). The simulation theorists (e.g., Harris, 1992) argued, however, that mental states concepts are not essentially theoretical postulates but rather derived from experience; whereas the modularity theorists claim that ToM is innate and matures (Baron-Cohen, 1995; Leslie, 1994). The current thesis is anchored on the socio-constructivist and evolutionary approaches where some precursors of ToM can be encountered at a very early age (and even in other mammals), and at the same time that an understanding of the mind is co-constructed by the child in the course of the development. From this perspective, three main conclusions can be drawn from a large corpus of research on ToM development: 1) infants display some understanding about the mind (e.g., Moll & Tomasello, 2012; Repacholi et al., 2014); 2) there are age-related changes in ToM development with a marked milestone around the age of 4-5 years (e.g., Pons & Harris, in press; Wellman & Liu, 2004); and that 3) these changes are affected by individual variability regarding different cognitive and social factors (e.g., Carpendale & Lewis, 2004; Marcovitch et al., 2015).

2.2.1 Precursors and age-related changes

Findings from comparative studies and research with infants have provided relevant information about ToM in non-humans primates as well as during the first years of life. Call and Tomasello (2008) revised the results from the seminal paper of Premarck and Woodruff (1978) by presenting new evidence suggesting that although chimpanzees can understand the goals, intentions, perception and knowledge of others, there is no empirical evidence that they can understand false beliefs. In a recent review on this issue, Meunier (2017) further highlighted that, despite the fact that monkeys lack mindreading abilities at a declarative level, they can display behaviors involving attention reading and perspective taking abilities, what they called behavior-reading versus mindreading. Infants can also use emotional communication to anticipate other's actions and, consequently, to coordinate behaviors in interactional contexts (e.g., Repacholi et al., 2014). Other studies have shown that infants can identify the difference between a deceptive and non-deceptive object when they are not exposed to two different perspectives simultaneously (Moll & Tomasello, 2012); they are also able to predict and anticipate other's actions in behavioral activities, and even show false-belief understanding when displaying helping behaviors (e.g., Buttelmann, Carpenter, & Tomasello, 2009). Moreover, infants' sensitivity to situations involving beliefs (Rakoczy, 2012) has been shown through their looking behaviors in violation of expectation (e.g., Onishi & Baillargeon, 2005; Träuble, Marinovic, & Pauen, 2010) and anticipatory looking (e.g., Southgate, Senju, & Csibra, 2007). Ruffman & Perner (2005) confronted Onishi & Baillargeon's (2005) findings by arguing that people may look to an object where they last saw it without the idea that the mind mediates the behavior. This perspective implies that humans have an inherited predisposition for behavioral rules, and that a mental understanding of behavior can be developed only within a social and cultural context. Although there is some controversy about whether or not infants' behaviors represent their understanding of the mind, or rather work as behavioral precursors of this mental understanding (Wellman, 2018 for review), it is possible to state that key ToM achievements in infancy are the distinction between agents and inanimate objects, expecting contingent responses from agents, directing other's attention with point and gaze, awareness of others' perceptions, goals and desires (e.g., Meltzoff, 2002; Sommerville & Woodward, 2005; Tomasello & Haberl, 2003).

During toddlerhood and the preschool years, children experience clear marked developmental changes in their ToM abilities, both quantitatively and qualitatively. This indicates that not only children understand an increasing number of mental and emotional states with age, but they also understand them in a different way (Pons & Harris, in press for review). For instance, between 2 and 4 years of age, children start to understand that the perception of an object changes when people look to the same object from different points of view. Flavell, Everett, Croft, and Flavell (1981) claimed that even under the age of 3, children recognize that people can perceive different objects at the same time (Level-1 perspective taking), but they have difficulties with recognizing that they can see the same object from different perspectives (Level-2 perspective taking). It is also between 2-3 to 4-5 years that children become able to recognize basic emotions and to understand the impact of external causes and desires on emotions. For example, from about 4 years of age they can recognize that two people with different desires can have different emotions when facing the same situation (Pons, Harris, & de Rosnay, 2004). From about 5 to 7 years of age they begin to understand the nature, causes and consequences of knowledge about the world, as well as the distinction between the appearance and reality of physical objects (e.g., Flavell, 1986; Gopnik & Astingtion, 1988). Moreover, they begin to acknowledge that people's behaviors are guided by their knowledge, whether true or false. This is also the stage where they can understand the difference between expressed and felt emotions, the impact of beliefs and memories on emotions and the impact of emotions on cognition. For instance, that emotions can vary depending on what people believe and expect from a given situation (Pons & Harris, in press). From about 8 to 10 years of age, they begin to understand second-order false-beliefs by recognizing that people can hold knowledge about other people's knowledge; they become able to understand moral and mixed emotions, and the possibility of emotion regulation. Therefore, the developmental changes come from a peripheral and superficial understanding of rather "visible or non-reflective" dimensions of the mind to a more "central and deeper" understanding of more invisible or reflective dimensions of the mind (Bender et al., 2015).

Even though ToM continues to develop over the school years, the clear improvement experienced by preschool children has led researchers to acknowledge this period as the one in which the acquisition of an understanding of the mind takes place. As a consequence of these marked developmental changes, it has, for many years, been a prevalent research practice to primarily assess children around the age of 5 (e.g., Apperly, Samson, & Humphreys, 2009), which has provided valuable knowledge about the social and cognitive factors contributing to the significant jump between 3 and 5 years of age, as well as individual differences in ToM development (e.g., Flavell, 2004; Shahaeian, Peterson, Slaughter, & Wellman, 2011).

2.2.2 Individual differences

Studies investigating individual differences in ToM development have indicated that age-related changes are also influenced by variability in children's cognition and their social environment. It is well documented that ToM development relies on the conversations children encounter in their families (e.g., Barreto et al., 2018; Meins et al., 2002), on children's own language skills (e.g., Cutting & Dunn, 1999; de Rosnay & Harris, 2002), intelligence, memory and executive functions (e.g., Hughes & Ensor, 2007; Melinder, Enderstad, & Magnussen, 2006; Marcovitch et al., 2015). Social relationships, such as attachment (e.g., Laranjo, Bernier, Meins, & Carlson, 2014), family's conversations about emotions, mother's sensitivity and responsiveness to her child's emotional needs (e.g., Cutting & Dunn, 1999; Pons, de Rosnay, Bender, Doudin, Harris, & Gimenez-Dasi, 2014), and relationships with peers (e.g., Cutting & Dunn, 2006; Wellman, 2018), have also been pointed out as crucial for ToM development. The positive impact of social interaction is also illustrated in studies showing that belonging to a larger family helps children develop false-belief understanding sooner (e.g., Cutting & Dunn, 1999; McAlister & Peterson, 2007). Astington and Hughes (2013) explain that this is probably due to a higher exposure to tricks, jokes, and teasing among siblings, as well as to talks about thoughts and emotions with the parents. Moreover, culture has an impact on the development of false-belief (e.g., Shahaeian et al., 2011), on the way children recognize, express, control the expression, regulate the experience, and speak about emotions (e.g., Mesquita, De Leersnyder, & Boiger, 2017). Nevertheless these individual and cultural differences, the hierarchical organization of ToM development has been found in many different cultures (e.g., Karstard et al., 2016; Shahaeian et al., 2011; Tang et al., 2017). Altogether, previous results suggest that an integrative framework of biological, cognitive, social and cultural aspects can account for the sequence of ToM development.

Despite some controversies on how ToM develops, what most researchers agree on is that social interaction is a key factor for ToM development, being one of the essential roots shaping social cognition. Interacting with others promotes a meeting of minds where people can express and talk about cognitive and emotional states, therefore becoming crucial for children's understanding of their own and other's mental and emotional worlds (Carpendale & Lewis, 2004). Nonetheless, there is less agreement about the degree to which having the knowledge about the mental world changes the way we interact and perform when working cooperatively in a problem-solving situation. On one hand, the development of ToM, the individual differences and causes of this development have been extensively investigated. On the other hand, we still know little about the impact of ToM on performances and children's social interactions in cooperative problem-solving situations. This gap is, therefore, addressed in this thesis: what are the cognitive and social consequences of acquiring ToM abilities?

2.3 What is Theory of Mind *for*?

ToM is strongly associated with self-reflection and social understanding, making up the capacity to understanding our own and others' mind intrinsically embedded in social interaction. Because the mental and social worlds form an intertwined relationship, it is relevant to understand not only how social interaction shapes social cognition, but also the extent to which – and if so how - ToM impacts social interaction. We consider social interaction as a context characterized by the regulation between individuals; this regulation implies that understanding an individual's action requires, among other things, the consideration of the actions of the other members in the group (Carvalho, Império-Hamburger, & Pedrosa, 1998). From this perspective, we can identify different levels or ways of interacting, e.g., a child's responsiveness to emotional clues at a very early age (e.g., Meltzoff & Moore, 1977), reciprocal regulations in cooperative activities (e.g., Viana & Pedrosa, 2014), and complex rituals in which several individuals in a group regulate each other's behaviors (Carvalho et al., 1998). In this thesis our focus relies on cooperation, and more specifically, on cooperative problem solving, which is a type of social and cognitive activity common in modern and formal school settings. The impact of ToM on social interaction is explored with respect to two interconnected stances: 1) the cognitive outcome produced in cooperation, which contributes to the understanding of potential cognitive and social consequences of ToM abilities; and 2) the extent to which children take the partner's perspective into account when resolving a cognitive problem together, shedding light on the debate about having and using ToM abilities in social interaction.

Studies investigating the potential social and cognitive implications of acquiring ToM have typically focused either on individual cognitive skills or social competences. There is clear evidence for the positive association between ToM and popularity, peer acceptance, school achievement, empathic responsiveness, and friendship (e.g., see Caputi et al., 2012; Farina & Belacchi, 2014; Lecce, Caputi, Pagnin, & Banerjee, 2017; Roazzi et. al., 2015; Slaughter, Imuta, Peterson, & Henry, 2015; Tornare, Czajkowski, & Pons, 2015; Wellman, 2018 for reviews). Particularly, Emotion Understanding (EU), one of ToM's main dimensions, has been found to be a strong predictor of children's psychological well-being, pro-social competences (including empathy) and school achievement (e.g., Pons & Harris, in press). There are also studies showing that having better ToM might even come with a cost. For instance, it has been documented that children with higher scores on false-belief tasks are also those who rate their ability more negatively after teachers' criticisms (e.g., Cutting & Dunn, 2002; Lecce, Caputi, & Pagnin, 2014). There are also studies suggesting that high ToM can be associated to social maladjustment. Sutton, Smith, and Swettenham (1999) have pointed out that superior ToM abilities might lead bullies to better manipulate others. Altogether, the findings are mixed. In some social contexts and cognitive activities, ToM seems to be a very powerful socio-cognitive tool that facilitates children's interactions with peers and their reasoning (Moore & Frye, 1991), whereas some results suggest that understanding the mind does not necessarily only have a positive impact on children's social life, and can even contribute to maladaptive behaviors.

Recently, there has been an increasing interest in studying the potential influences of ToM on school readiness, which includes cognitive and social skills relevant for learning, such as leadership, motivation and academic performance (Wellman, 2018 for review). Typically, the impact of ToM on academic performance is assessed in terms of individual cognitive learning outcomes in reading and math abilities (e.g., Lecce et al., 2014; Strasser & del Río, 2014). However, working in cooperation might also be a relevant process learning skill. As such, we lack knowledge on whether ToM has positive implications for the cognitive outcome produced in social interaction, and for the way children interact in cooperative problem-solving situations. Furthermore, previous studies have frequently assessed ToM and children's social interaction and conversational skills through teachers' report or when the child interacted with a peer-like puppet and not with a real partner (e.g., Bartsch, Wade, & Estes, 2011; de Rosnay, Fink, Begeer, Slaughter, & Peterson, 2014). More studies of children in direct interaction with other children are therefore needed to further our knowledge on the implications of ToM for children's learning processes and outcomes. In addition, the disproportionate focus on false-belief reasoning seems to underestimate the contribution of other ToM abilities, such as perspective taking and emotion understanding (e.g., Piek, Bradbury, Elsley, & Tate, 2008; Sebanz, Bekkering, & Knoblich, 2006). There is subsequently a need to include a broader measure of children's understanding of the mind in order to get a clearer picture of the consequences of ToM for cooperative problem-solving among school-age children.

It is noteworthy that the often asked question "what ToM *is for*?" is connected to the classical discussion about the relation between declarative and procedural knowledge. Thus, before reviewing the specific literature concerning the relationship between ToM and cooperative problem-solving, we will first explore the controversy between continuity versus discontinuity between ToM as declarative knowledge and ToM as procedural skill.

2.4 Theory of Mind: Declarative knowledge and procedural skill

Today, there is no consistence about the terminology used to refer to two different dimensions of ToM, i.e., ToM displayed in standard task (explicit, deliberate, declarative, later system, abstract, not content/context non-specific) and ToM used in a more spontaneous way (implicit, automatic, procedural, early system, concrete, content/context specific) (e.g., Schneider, Slaughter, & Dux, 2017; Pons & Harris, in press). In this thesis we use the terms declarative knowledge and procedural skill. ToM as a declarative knowledge here refers to the understanding of the mind at a meta-representational level, in which the child's knowledge is explicitly declared when asked about others' mental and emotional states and processes (Astington & Hughes, 2013; Ruffman, 2014; Pons & Harris, in press). Although false-belief is still the most frequent task used to assess declarative ToM, a wide range of different tasks have been developed (e.g., Pons et al., 2004; Wellman & Liu, 2004; Boucher, Pons, Lind, & Williams, 2007). Despite their distinctness in terms of which mental concept they evaluate (e.g., perspective-taking, false-belief, emotion comprehension), the age range tested, and whether the test is based on a single task paradigm (e.g., only assessing false-belief), or a multi-concepts assessment (e.g., using a broader ToM test), they share at least one important feature: they are frequently used in individual settings were children have to think, for example, from the perspective of a story's character in a fictional narrative by explicitly answering to a sentence-like question. On the other side, ToM as procedural skill can be linked to a usage-based approach (Liszkowski, 2013) in which ToM is used in a more spontaneous way during direct/natural social interaction through behaviors, gestures and verbal communications that indicate, for example, action prediction and perspective taking. Thus, ToM as a procedural skill means that the child uses ToM while acting in the social world, e.g., when trying to resolve a problem with a partner. Based on the distinction proposed by Flavell (2000) about metacognitive knowledge (understanding how minds work) and metacognitive processes (regulating thoughts before, during and after their completion), we can relate ToM as declarative knowledge to the ability to represent explicitly (*to know the mind*), whereas ToM as procedural skill relates to performance (*to regulate the mind)*, (e.g., Flavell, 1979; Pons & Harris, 2001). Table 1 summarizes their main features.

Table 1 *Declarative ToM X Procedural ToM*

Declarative ToM	**Procedural ToM**
More or less conscious *knowledge* about the nature, causes and consequences of the mind in the self and others	More or less conscious *activities* to recognize, express and control the mind in the self and others
General/context free	Context specific

The debate about the relationship between procedural and declarative knowledge has a long tradition in developmental psychology in general, and in the ToM field in particular. The main question in this debate is whether these two types of knowledge are related to each other, and if so, to what extent one is a precondition of the other (see Christensen & Michael, 2016; Pons, Harris, & de Rosnay, 2012 for discussion). Currently, we can identify two main hypotheses for this question: 1) a discontinuous relationship (independent modularity) in which there is no interaction or relation between declarative knowledge and procedural skill; 2) a continuous relationship (dependent modularity) in which the two systems are somehow related to each other.

The idea of discontinuity between procedural skill and declarative knowledge implies that they develop concurrently but follow two independent developmental trajectories (Mandler, 1988). Butterfill and Apperly (2013), for instance, have argued for a two-system ToM in which the early-developing system would be implicit, efficient and automatic, while the later-developing system would be explicit, slower and more flexible. This trade-off between efficiency and flexibility would make the two systems to work in parallel. In this way, an individual could be very efficient in tracking beliefs in social interaction (procedural skill) without being able to represent these beliefs as such (declarative knowledge); in the same way that adults could be inefficient in using ToM abilities even when they are able to understand mental state concepts (Surtees & Apperly, 2012). The main explanation for this discontinuity is that taking the speaker's perspective in social interaction could demand an effortful monitoring process of adjustment, and that even when there is a motivation to appreciate the other's knowledge, people do not necessarily use their ToM abilities to interpret the other's communication (e.g., Apperly et al., 2010; Apperly, 2011; Surtees & Apperly, 2012). However, this hypothesis has been very provocative and debatable (Schneider et al., 2017). Several results suggest that the difficulty in performing what one is capable of understanding does not necessarily mean that the two types of knowledge do not interact (e.g., Pons & Harris, 2001; Pons et al., 2012). This has led several scholars to argue in favor of a continuous relationship between procedural and declarative knowledge.

The idea of continuity between procedural and declarative knowledge suggests that these two systems are somehow interconnected. Within this approach three hypotheses have emerged about how this relationship might occur. The first explanation, which builds on Piaget's conception of the grasp of consciousness, defends the existence of a developmental trajectory from "success" to "comprehension", from procedural to declarative knowledge (Pons & Harris, 2001; Pons et al., 2012 for review). In this view, children are first able to do and later able to reflect upon and understand their own actions. Thus, success in doing is a requirement for their understanding, e.g., infant's application of their ToM abilities is a precondition for the development of ToM at the representational level. Although there is a trend in investigation of the developmental trajectory from procedural ToM (displayed by infants) to declarative ToM (displayed by preschool children) (e.g., Brooks & Meltzoff, 2015; Wellman, Lopez-Dura, Labounty, & Hamilton, 2008), another alternative explanation of the developmental continuity proposes the opposite trajectory: declarative knowledge as preceding procedural skill. For instance, when children understand strategies to control emotion, they become more capable to use it in their life (e.g., Harris, 2000). A third explanation suggests a cooperative multi-system paradigm (Christensen & Michael, 2016) in which the relationship between the two types of knowledge can be seen as a shape of spiral (Pons & Harris, in press). Based on Pons & Harris (in press) explanation about the circular relationship between emotion understanding and emotion experience, we can describe this spiral with regard to ToM as such: procedural ToM - which originally is more automatic and less conscious - is transformed by improvement in children's declarative knowledge about the mind that consequently results in new forms of using ToM abilities in social interaction; at the same time as less sophisticated declarative ToM is transformed by the use of these abilities in social interaction and will, therefore, become more sophisticated at the representational level. We highlight that more studies investigating this circular approach has been called for (e.g., Christensen & Michael, 2016: Pons & Harris, in press).

Furthermore, the findings about the relation between having and using ToM abilities are mixed. For instance, Veneziano, Albert, and Martin (2008) found that children between 3 and 9 years of age with higher scores on ToM tests were better able to express epistemic states when they narrated a story; and they were also more aware of their thoughts involved in reading (Guajardo & Cartwright, 2016; Lecce, Zocchi, Pagnin, Palladino, & Taumoepeau, 2010). Contrarily, Meins, Fernyhough, Johnson, and Lidstone (2006) showed that between 6 and 9 years of age, having ToM capacities, measured through conceptual tasks, is different from being able to use it either to narrate a book or to describe friends. We argue that investigating the impact of declarative ToM (measured with standard tasks) on procedural ToM (children's use of ToM in social interaction) would contribute to this current debate. Even though previous studies have looked at ToM in social interaction, it remains unclear whether having these abilities at the declarative level can explain the way children interact when solving cognitive problems with a partner, and their cognitive outcome produced cooperatively. Answering this question can contribute to the controversy about continuity versus discontinuity between declarative and procedural ToM, and it potentially provides a better explanation of the cognitive and emotional mechanisms underlying cooperation. As a practical consequence, addressing this question might have significant contribution to the educational field, as working cooperatively is frequently demanded in modern educational settings such as schools.

3 Cooperation

3.1 Cooperative problem-solving

Cooperation can be defined as an activity where participants share a joint goal, take complementary roles, and are motivated to help one another in order to achieve a given task (Moll & Tomasello, 2007). It is a type of interaction where children go beyond reacting to what others are doing and rather need to anticipate what others will do, as well as negotiate distinct points of view (Call & Tomasello, 2008) in order to successfully resolve a task. From a developmental account, previous studies have shown that children begin to succeed in cooperative problem-solving tasks that demand behavioral coordination from their second year (e.g., Brownell, Ramani, & Zerwas, 2006), and that they can coordinate complementary roles without the support of adults from the age of 2 (Eckerman & Peterman, 2001). By the age of 3, they become capable of helping each other in solving a task that cannot be completed individually (Hamann, Warneken, & Tomasello, 2012). Further, due to a substantial improvement in language and other cognitive and social skills (e.g., Satta, Ferrari-Toniolo,Visco-Comandini, Caminiti, & Battaglia-Mayer, 2017), school-age children can engage in more sophisticated types of cooperative problem-solving, both at the mental level, such as math problems, and at the behavioral level, for instance, more advanced forms of cooperative games.

Research on the impact of cooperation among school age children has been flourishing, primarily because in middle childhood children frequently engage in cooperative problem solving in school settings. Whereas there are some studies showing the cost of cooperation, as cognitive opposition can cause problems for social relations, for instance, high levels of aggression and peer rejection (e.g., Haselager, Cillessen,Van Lieshout, Riksen-Walraven, & Hartup, 2002), the literature provides robust findings on the benefits of cooperation for cognitive growth. A large body of studies has found that on a wide range of cognitive problems, children perform better when working with a partner compared to when they work on the same problem alone (e.g., Doise & Mugny, 1984; Satta et al., 2017; Zapiti & Psaltis, 2012). Earlier findings have also shown evidence that this "cooperation benefit" (Satta et al., 2017) has long term-effects as children develop a better understanding of problems (Azmitia & Montgomery, 1993), as well as retain the knowledge acquired from the problem-solving interaction (Tudge, Winterhoff, & Hogan, 1996). A vast amount of studies have demonstrated that children progress on the task when working cooperatively in problems, for example, related to conservation (Miller & Brownell, 1975), spatial transformation (Doise & Mugny, 1984; Zapiti & Psaltis, 2012), and action coordination (Doise & Mugny, 1984; Satta et al., 2017). According to Tomasello, Carpenter, Call, Behne, and Moll (2005, p. 681), cooperation requires that "each participant represents both roles of the collaboration in a single representational format – holistically, from a bird's-eye-view, as it were – thus enabling role reversal and mutual helping". The complexity of this process makes cooperative problem-solving a social setting in which several behavioral and social-cognitive skills are simultaneously applied. Surprisingly, the impact of ToM on cooperative problem-solving has not been studied extensively, and the few studies available are very often restricted to false-belief reasoning. We argue that working cooperatively on a joint goal seems to demand an appreciation and understanding of other's mind and emotions, and due to that cooperative problem-solving becomes a suitable context to analyze the impact of ToM on both the way children interact and their cognitive outcome in social interaction.

In this thesis we address the question of the extent to which ToM explains the way children interact and their cognitive performance in two types of cooperative problem-solving: spatial transformation and sensorimotor tasks. Spatial transformation demands the ability to mentally rotate objects and make transformations in their positions based on a specific referential mark (Hegarty & Waller, 2004). When Piaget and Inhelder (1948) focused on one aspect of spatial relations called "coordination of perspectives", they were referring to the ability to identify the appearance of an object as something dependent on the spatial position from which they are viewed. Resolving spatial transformation problems in cooperation, consequently comprises both the cognitive process of projecting relationships between objects, and the social process of understanding the relation between two different perceptions, as exemplified by the "If I were in your place I would see what you see" line of thinking (Fishbein, Lewis, & Keiffer, 1972). The sensorimotor task used in the studies presented in this thesis demanded action coordination, which involves the ability to couple relevant perceptual information, such as coordinating vision and grasping, and to integrate different and interdependent body movements, such as synchronizing the actions of separate limbs and coordinating sensorimotor behaviours together with a partner (Getchell, 2006).

Coordinating actions demands that two or more individuals, by playing complementary roles, divide up the labor, adjust and align their sensorimotor actions to achieve a common goal (e.g., Call & Tomasello, 2008; Carpenter, 2009; Grüeneisen, Wyman, & Tomasello, 2015; Moll & Tomasello, 2007; Warneken, Steinwender, Hamann, & Tomasello, 2014). Although sensorimotor and spatial transformation cooperative problem-solving tasks require coordination of perspectives and actions, the literature shows limited and mixed findings about the role of ToM for task performance and children's interactions in resolving these type of tasks. Would ToM be one of the cognitive processes explaining what makes children take advantage of the cooperative situation?

3.2 Does Theory of Mind facilitate cooperative problem-solving?

There is robust evidence showing that the levels of a child's expertise on the task, the generation of socio-cognitive conflicts, quality of verbal discussion, and imitative strategy (e.g., Azmitia, 1988; Butera, Darnon, & Mugny, 2011) are amongst the cognitive and social factors explaining performance in cooperative situations. For instance, Satta and colleagues (2017) have recently showed that improvement in inhibitory control reduces egocentric bias and facilitates the monitoring of peer's actions and the implementation of a common action plan (Meyer, Bekkering, Haartsen, Stapel, & Hunnius, 2015). Another alternative line of research called the mirror coding system paradigm defends that by observing other's actions we spontaneously activate our own motor systems due to a common coding of perception and action, meaning that the same representations are used to perceive and perform an action. Sebanz and Knoblich (2009) argue that the mirror coding system can not only help simple joint actions such as imitation (Meltzoff & Moore, 1977), but also more complex forms of social action because they support the prediction of other's behaviors which, consequently, could help the performance of complementary actions essential for cooperation. Sebanz, Bekkering and Knoblich (2006) suggested that more studies should address the extent to which coordinating actions and perspectives in social interaction relies also on ToM, as these activities demand representation sharing, joint attention, actions' prediction, intention attribution and the ability to plan actions with a partner (e.g., Meyer et al., 2015; Tomasello, 2000; Warneken, Chen, & Tomasello, 2006).

Among school age children, previous studies have demonstrated that 6- to 10-year-olds are capable of using first- and second-order false beliefs to make predictions and coordinate their actions with peers, therefore producing better outcome in cooperative activities (e.g., Curry & Chesters, 2012; Flobbe, Verbrugge, Hendriks, & Krämer, 2008; Grüeneisen, et al., 2015). On the contrary, Surtees & Apperly (2012) have shown that adopting others' perspectives remains cognitively demanding even for adults, especially when the perspectives are conflicting (Keysar, Barr, Balin, & Brauner, 2000; Epley, Morewedge, & Keysar, 2004; Qureshi, Apperly, & Samson 2010), which is usually what happens during cooperative problem-solving. In interactive contexts demanding persuasive abilities – such as cooperative problems - the results are mixed. Some have not found any relationship between false belief and persuasion among children from 3 to 6 years of age (Bartsch, et al., 2011), while others have presented evidence that ToM correlates significantly with mindful real-world conversation skills (de Rosnay et al., 2014) and persuasion skills in children from 3 to 12 years of age (Peterson, Slaughter, & Wellman, 2018). Moreover, Reschke, Walle, and Dukes (2017) also emphasize that research has frequently underestimated the contribution of children's emotion understanding to their appreciation of other's behaviors when coordinating actions with others (Zhang, Dumas, Kelso, & Tognoli, 2016).

We argue that one way that ToM might influence cooperative problem-solving is by promoting constructive socio-cognitive conflict resolution. Cooperation is indeed a rich context for the emergence of socio-cognitive conflict as it promotes a meeting of distinct – and very often conflicting – perspectives, potentially provoking dissent and discussion (Butera et al., 2011); and studies have shown that solving socio-cognitive conflicts by coordinating different viewpoints could lead to more efficient cognitive outcomes (e.g., Darnon, Buchs, & Butera, 2002; Doise & Mugny, 1984; Zapiti & Psaltis, 2012). Would ToM help children being open to another's perspective during socio-cognitive conflict?

Traditionally, socio-cognitive conflict has been studied by two main approaches: the structural perspective based on Piaget's theory, and the procedural perspective based on Vygostsky. In the "three mountains task" used by Piaget and Inhelder (1948), children received a viewer rotation instruction (Aichhorn, Perner, Kronbichler, Staffen, & Ladurner, 2006) and had to visualize themselves in different positions. In this situation, they were required to see the same scene from different perspectives, therefore potentially creating an intra-individual conflict. Based on a critical review of Piaget and Inhelder's (1948) work, Doise and Mugny (1984) reinterpreted Piaget's original idea from a Vygotskyan procedural position, focusing on the building of knowledge in problem-solving interaction (Gauducheau & Cuisinier, 2005). They proposed a series of experiments where the coordination of real viewpoints could take place and the disagreement between partners could provoke changes in the individual response. In a socio-cognitive conflict, the individual is provoked to doubt her/his own solution for the problem, which in turn can cause decentration from one's point of view and consideration of the other's knowledge and ideas (Butera & Buchs, 2005). Following this rationale, opposition triggers elaboration, which, in turn, foster attempts to joint resolution.

A conclusion derived from findings based on this procedural Vygotskyan approach was that not all types of social interaction operate in a way that facilitates perspective taking and, consequently, cognitive growth (Buchs, Butera, Mugny, & Darnon, 2004; Sommet, Darnon, & Butera, 2015). This is because in some situations the relational conflict can surpass the epistemic conflict, leading to a competitive relationship in which the main focus of the participants is to prove their own competence, which again makes them less prone to questioning themselves and to think from the other's perspective (Darnon et al., 2002; Sommet et al., 2015). Johnson, Johnson, and Tjosvold (2006) argue that the value of the intellectual conflict is truly positive when participants can build a constructive controversy, and this exists when they "unfreeze" their cognitive process by activating epistemic curiosity and an open attitude to others' influence and knowledge, consequently accommodating the perspectives and reasoning of others. Previous studies have pointed out that we can facilitate cooperation, and thereupon constructive conflict resolution, when children are engaged in a symmetrical relationship in terms of age, gender, and knowledge (e.g., Busch et al., 2004; Sommet et al., 2015). Busch & Butera (2004) also argue that cooperation can be promoted when the cooperative context operates with interdependent resources, where children have access to different but complimentary resources to resolve the task.

Nevertheless, even when creating scenarios that aid collaboration, children might deal with the socio-cognitive conflict differently. Children have been found to be more sensitive e to their partners' perspectives in a comprehension task by around the age of 5 (Nadig & Sedivy, 2002); and around the age of 9 they become more skillful in using argumentative reasoning when faced with a socio-cognitive conflict, while younger children tended to either reject or accept the other's viewpoint (Gauducheau & Cuisiner, 2005). Suddendorf and Fletcher-Flinn (1999) have demonstrated that children with higher scores on false-belief tasks were more capable of finding divergent answers to a given problem. However, they have not examined the role of ToM in situations where the child needs to be more flexible toward another's repertoire of knowledge when this contradicts his/her own repertoire. There are indeed studies suggesting that being flexible and open to other's knowledge involve executive functions, which play a role in inhibiting self-knowledge and consequently integrating other's viewpoints (e.g., Ruby & Decety, 2003). Taking into account the positive link between ToM and inhibitory control (e.g., Carlson & Moses, 2001), it appears self-evident that the acquisition of ToM would make children more able to coordinate perspectives and actions in cooperative problem-solving situations. However, to the best of our knowledge, no study has investigated whether ToM (declarative knowledge) and the tendency to have a more rejecting or receptive attitude toward the other's perspective in social interaction (ToM as procedural skill) are related competences.

4. Summary

The review of the literature presented above showed robust findings with regard to the development of ToM and its social and cognitive antecedents, pointing out social interaction as one of the essential roots in this development. Nowadays, there is an increasing tendency to investigate the reverse relationship, i.e., the social and cognitive consequences of acquiring ToM. However, there are still some gaps and limitations in these previous studies: 1) the studies focus on belief reasoning without including other cognitive and emotional ToM concepts; 2) they have not extensively explored the relation between children's performance on declarative (sentence-like) ToM tasks and their social interaction in cooperative problem-solving; 3) few studies have investigated this impact among school-age children; 4) they predominantly use an experimental design in which children usually interact with the experimenter or with a puppet-like person; 5) they lack information on whether ToM affects peer interaction in situations where children can use their mental state understanding more spontaneously; 6) they show mixed findings about the relation between having ToM and using these abilities to take the perspective of a real partner.

Investigating the impact of school-age children's ToM (declarative knowledge) on the way they interact (procedural skills) with another child and their performance in cooperative problem-solving tasks is a valid way to advance our knowledge about the positive implication of children's ToM on their social interaction and cognition. We highlight also that assessing the impact of ToM in middle childhood is relevant for three main reasons. First, the development of ToM does not cease in preschool years. As already mentioned, school-age children begin to understand recursive mental states in which, for instance, they acknowledge that people have beliefs about the content of other's mind; they also start to understand mental components of emotions such as the impact of beliefs and memories on emotions (Pons et al., 2004), and use more irony and metaphor, making them more sensitive to the interpersonal dynamics of social situations (Astington & Hughes, 2013). Second, even studies assessing children above the age of 6 years focus on conceptual tests (e.g., second-order false-belief tasks, double-bluffs) rather than whether these abilities are expressed and /or impact social interaction and performance in cooperative problem-solving situations. Third, coordinating actions and perspectives are an essential part of school activities, and it is strongly related to important social competencies in middle childhood, such as cooperation and helping behaviours (Cirelli, Einarson, & Trainor, 2014; Kirschner & Tomasello, 2010). We assume that schooling is not only crucial for the development of a declarative ToM (Astington & Hughes, 2013), but that it is a relevant phase and social setting where children can apply the declarative knowledge about the mind they have acquired during the preschool years.

5 Aims of the thesis

The overall aim of this thesis was to examine to what extent children's ToM impacts their performance and the way they interact with another child in cooperative problem-solving tasks.

Paper I

The main aim of Paper I was to investigate the impact of ToM – including the understanding of cognitive and emotional states – on children's performance in a cooperative spatial transformation task. More specifically to examine a) whether children improve their performance when resolving the task with a partner as compared to alone; and b) to what extent children's ToM explains their performance in the cooperative condition of the task, accounting for age, gender and performance in the individual condition. Figure 1 illustrates the main relation explored in this paper.

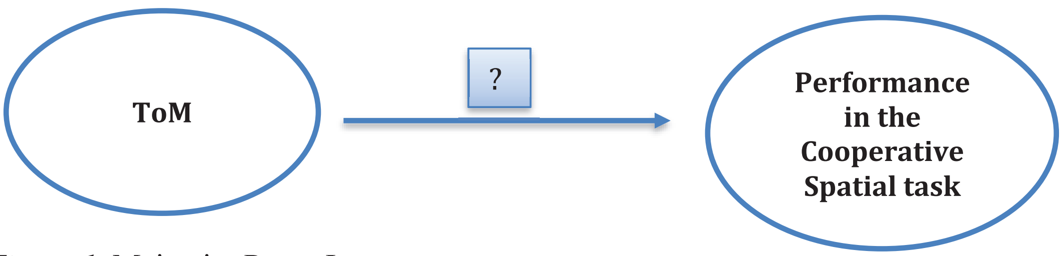

Figure 1. Main aim Paper I

Paper II

The main aim was to investigate the extent to which Emotion Understanding (EU) explains children's performance in a cooperative sensorimotor task. More specifically to examine a) whether EU and performance in the individual and cooperative conditions of the sensorimotor tasks are related; and b) whether EU can account for performance in the cooperative condition when age, gender and performance in the individual condition are taken into account. Figure 2 illustrates the main relation explored in this paper.

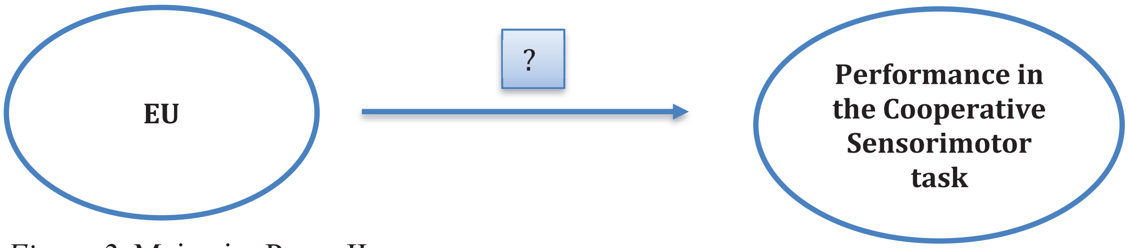

Figure 2. Main aim Paper II

Paper III

The main aim was to investigate the impact of ToM – including the understanding of cognitive and emotional states – on children's attitudes toward another's perspective in a cooperative spatial task, and to what extent it affects their cognitive performance. More specifically to examine a) whether children's level of ToM can explain their attitudes toward another's perspective when they are faced with socio-cognitive conflicts, when controlling for age and gender; and b) to what extent ToM as declarative knowledge (ToM standardized task performance) and ToM as procedural skill (attitude toward another's perspective during socio-cognitive conflict) might account for children's performance in the cooperative spatial task. Figure 3 illustrates the main relations explored in this paper.

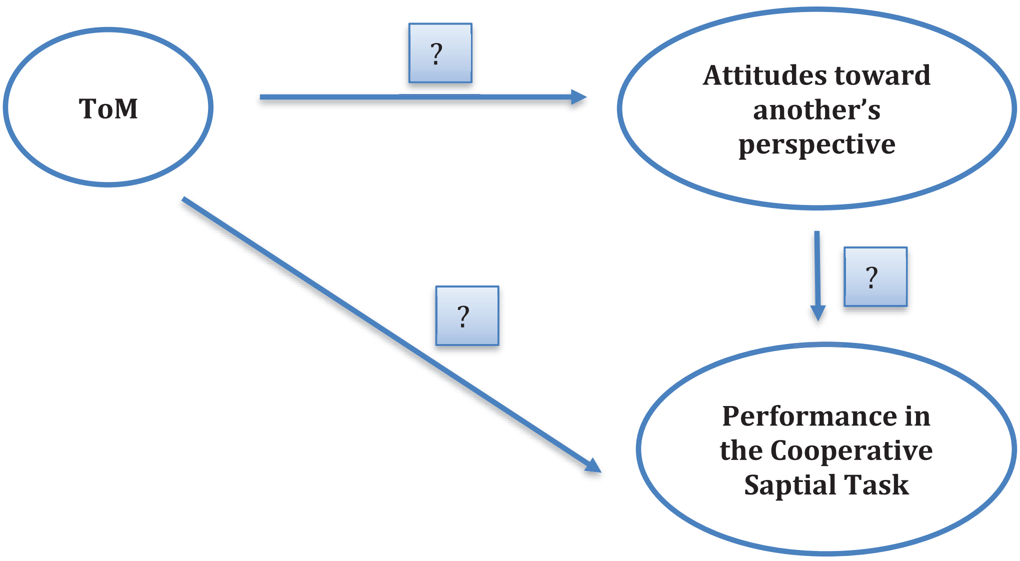

Figure 3. Main aim Paper III

6 Methods

The studies described in this thesis are part of the project entitled "Investigating the relationship between children's theory of mind and their social interactions with peers and teachers at school" which was designed by the PhD candidate and her main supervisor. The data to be presented were collected in 2013 through individual assessment in ToM tests, as well as video recordings of peer interaction in two types of cognitive tasks: sensorimotor and spatial transformation problems.

6.1 Ethical considerations

The data collection was initiated after the approval by The Norwegian Social Science Data Service (approval number 29780/3) and the Ethic Committee in Brazil (approval number 213.212). The PhD candidate – who was the person responsible for the data collection – first contacted the heads of two private schools in Recife, a city located in the Northeast of Brazil. After their authorization through a letter of agreement, the parents received a written consent form informing the aims and the procedures of the study. Thereby, the children who got the authorization from the parents received verbally information about the methodological procedures and were asked about their willingness to participate in the study. Although children are not officially entitled to authorize their own participation, their wish and availability were respected. Importantly, the researcher was available to clarify any questions or doubts about the study throughout the data collection process, and the children or the parents could withdraw their participation at any time point if they wanted to.

6.2 Participants

First, 120 parents of typically developing children with Portuguese as their native language were contacted through two middle-class private schools in Recife (Brazil). The parents of 90 children (75% of the invited) authorized their children to be asked to participate, and all of them, subsequently, agreed to be part of the study. To avoid floor and ceiling effects, children who did not succeed on the simplest item in the individual condition of either the spatial transformation or the sensorimotor task (n = 14), as well as those who achieved the maximum score in the individual condition of the spatial task (n = 10) or in the individual condition of the sensorimotor task (n = 8) were excluded from the sample (Doise & Mugny, 1984). This choice ensured that the children could have the same minimum level and that they could also progress on the task.

The sample in Paper I included 66 children (32 boys; 34 girls) between 5 years 7 months and 9 years 8 months (*M* = 89.94 months; *SD* = 13.09 months), and age groups were created aiming to obtain more variation in terms of ToM abilities. The younger group (*n* = 36: 5y7m–7y5m) had the understanding of the reflective dimension of the mind in progress and the older group (*n* = 30: 7y6m–9y8m) had more established reflective ToM abilities. In Paper II, the sample was composed of 68 children (32 boys; 36 girls) between 5 years 7 months and 9 years 8 months (*M* = 90.57 months; *SD* = 13.36 months). Aiming also to generate variability in terms of Emotion Understanding (EU) (the older group with more mental/reflective levels consolidated than the younger group), children were divided into two groups according to their age (*n* = 34 in the younger group: 5y7m-7y5m; *n* = 34 in the older group: 7y6m-9y8m). The same sampling criteria used in Paper I was applied in Paper III, but because one female dyad had to be excluded due to technical issues related to the video recording, which did not allow us to code the interaction, the sample was consisted of 64 children (32 boys; 32 girls) between 5 years 7 months and 9 years 8 months (*M* = 90.14 months; *SD* = 13.25 months), with 34 children in the younger group (5y7m-7y5m), and 30 children in the older group (7y6m-9y8m).

The dyads were composed of children of the same gender, similar age, from the same classroom, and with similar performances on the individual condition of the spatial and the sensorimotor tasks, and the ToM and EU tasks. Composing dyads with children who were very much alike was a strategy to promote cooperation, as previous research have shown that asymmetry in knowledge and gender might create competitive relationships instead of collaborations (Buchs et al., 2004; Sommet et al., 2015). Information from the children's ranking of their friends in the classroom was also used when composing the dyads in order to ensure that the children were neither best friends nor not friends. This procedure was employed to guarantee that children could have similar opportunities to cooperate, thus avoiding potential advantages of interacting with a best friend (well-known partner) and reducing the disadvantage of getting into social conflicts when interacting with a disliked classmate (e.g., Kuhnert, Begeer, Fink, & de Rosnay, 2017).

6.3 Material and procedures

The data collection consisted of five sessions which took place at the children's schools. The first and second sessions aimed at individually assessing children in the sensorimotor task – the "Labyrinth ball game" – and in the spatial transformation task called the "Reconstruction of the village". These sessions were video recorded and the order of the tasks was counterbalanced, so that half of the sample was first tested in the sensorimotor task while the other half was first assessed in the spatial transformation task. After about 15 days, children's ToM were assessed with the Theory of Mind Test (TMT, Pons & Harris, 2002), and the Test of Emotion Comprehension (TEC, Pons & Harris, 2000). The fourth and fifth sessions were carried out around 10 days after the third encounter, and children participated in the cooperative condition of the sensorimotor and the spatial transformation tasks. Once again, the order of the tasks was counterbalanced. Each session of the data collection lasted around 10 minutes.

We highlight that the observation through video recording is particularly relevant when one aims to analyze not only task performance but also the interactional process and how children's behaviors regulate the ongoing interaction. Particularly in Paper III, the video recording was used for more systematic observation and coding, allowing us to play back visual and audio components of the scene under investigation (Pedrosa & Carvalho, 2005; Smith, 2011).

6.3.1 Theory of Mind Test (TMT)

There is an increasing trend in evaluating ToM abilities by including assessment of multiple concepts, rather than through a single-task paradigm (Wellman & Liu, 2004). By using a multi-task assessment based on the sequence of ToM development it is possible to capture children's developing understandings across a range of conceptions not limited to false-belief. Wellman and Liu (2004) emphasize that when studying the role of ToM as an independent factor enhancing other developments, e.g. social interaction, a multi-task paradigm could provide a clear measure related to individual differences. Due to that, the studies presented in this thesis assessed children's ToM through the Theory of Mind Test (TMT; Pons & Harris, 2002).

The TMT consists of an A4 picture book with a simple cartoon scenario (or picture) on each page evaluating 10 components of cognitive understanding (e.g.

Flavell, 2004) with three items each: (a) Level 1 of perspective taking, (b) Level 2 of perspective taking, (c) comprehension of intentionality, (d) comprehension of ignorance, (e) comprehension of false belief, (f) comprehension of the distinction between appearance and reality, (g) comprehension of lies, (h) comprehension of jokes, (i) comprehension of second-order false belief, and (j) comprehension of double bluff. For each item, the examiner shows a drawing while reading a story regarding the depicted characters. After hearing each story, the child is asked to attribute a cognitive mental state to the main character of the story by pointing to one of the two possible answers illustrated below the scenario, e.g., ‘‘What do I see, a cat ?—or a dog?’’; ‘‘What will the girl think is in the box, strawberries?— or peanuts?’’ (e.g., Boucher et al., 2007).

6.3.2 Test of Emotion Comprehension (TEC)

Many different instruments that measure Emotion Understanding (EU) have been developed in the past years (Castro, Cheng, Halberstadt, & Grühn, 2016 for review). However, most of them are time-consuming, they need expertise and assess only a few core components of EU. In addition, they are frequently language demanding or can be used only with younger children or older, but not with both. These limitations inspired the construction of the Test of Emotion Comprehension (Pons & Harris, 2000), which is the test used in the studies presented in this thesis. The TEC also consists of a picture book containing cartoon scenarios, which are accompanied by various descriptions and stories designed to test children's understanding of emotions. The TEC assesses nine different core components of emotion understanding: recognition of basic emotions – happy, sad, angry, scared, alright (five items), understanding of the impact of situational variations on emotions (five items), understanding of desire-based emotions (four items), understanding the impact of beliefs on emotions (one item), the understanding the impact of memories on emotions (one item), understanding the control of the expression of emotions (one item), understanding the regulation of the experience of emotions by the mean of reflective psychological strategies (one item), understanding the mixed nature of emotions - ambivalence (one item), and understanding moral and reflective emotions – pride, shame, guilt (two items). Each scenario comes with four possible emotional outcomes, represented as the facial expressions of the story protagonist, which are left blank in the scenario itself. After children are introduced to the individual scenario and the experimenter read the accompanying story, children are asked to attribute an emotion to the story protagonist(s) by pointing to the most appropriate of the four possible emotional outcomes. For example, to assess participants' understanding of the impact of situational variations on emotions the following story was told: 'This girl is being chased by a monster. How is she feeling? Happy, sad, just alright or scared?' (e.g., Pons, et al., 2004 for descriptions of the instrument). The TEC has been translated into 25 languages and it has shown good test-retest reliability, as well as concurrent, criterion and construct validity. It has been standardized in Italian and Portuguese (see e.g., Pons et al., 2014 for a recent review).

6.3.3 Sensorimotor task

Children were first tested individually and then in a cooperative condition in a task called the "labyrinth ball game", in which they had to balance a ball around different holes using two adjusting knobs to tilt the board (see Figure 4 bellow). We chose this task because it requires the coordination of actions similar to the game used in the studies conducted by Doise and Mugny (1984), and it is suitable to be played by a single child from around the age of 6, as well as by two children at the same time. In addition, the game is fun, and children are generally motivated to play it. When performing the task alone (individual condition), the child had to use both hands, one on each knob, to guide the steel ball through the maze. When the child played with a partner (cooperative condition), the two children held one knob each, which demanded coordination of actions and perspectives between the two children.

Figure 4. The Labyrinth Ball Game

Figure 5 shows the removable boards with the different levels used in this study, with the blue dots indicating which holes were covered up in order to create variation in the difficulty of the task. The first and the second levels displayed in the upper part of the figure used the same board design, but they had five and eight holes, respectively; the third and the fourth levels presented in the lower part of the figure had a more complex labyrinth design than the first two levels, with 11 and 14 holes, respectively. Children were allowed to have maximum five trials in each level. Because some children might be more skilful when handling one specific knob in the cooperative condition—as each knob demanded different types of movements—the children exchanged positions when they moved to the next level.

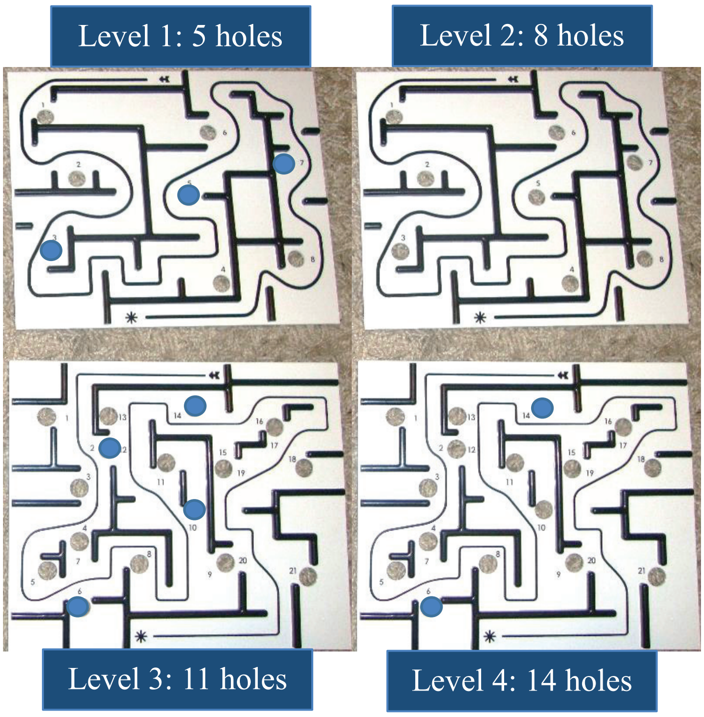

Figure 5. Levels of the labyrinth ball game.

6.3.4 Spatial transformation task

Children were first tested individually in an adapted version of the spatial transformation task "the reconstruction of the village", developed by Doise and Mugny (1984) and derived from Piaget's famous "three mountains" task (Piaget & Inhelder, 1948). Figure 6 provides an overview of the task. The task material included a miniature village placed on a cardboard model (50cm by 50cm) that was fixed on a table, and which comprised a lake (the referential mark) and three or four houses of different colors and marked with doors on one side. On a different table, offset 90º to their left, children placed in position Y could see another cardboard also marked with a lake on it (position X refers to the partner's position in the cooperative condition of the task to be described bellow). They were given three or four houses similar to those previously placed by the researcher on the cardboard model, and they were instructed to replicate the village they could see. The researcher said that if a man comes out of the lake, he would find the houses in the same positions as the ones in the model constructed by the experimenter. Chairs were placed in such a way that the children could not move beyond a limited area.

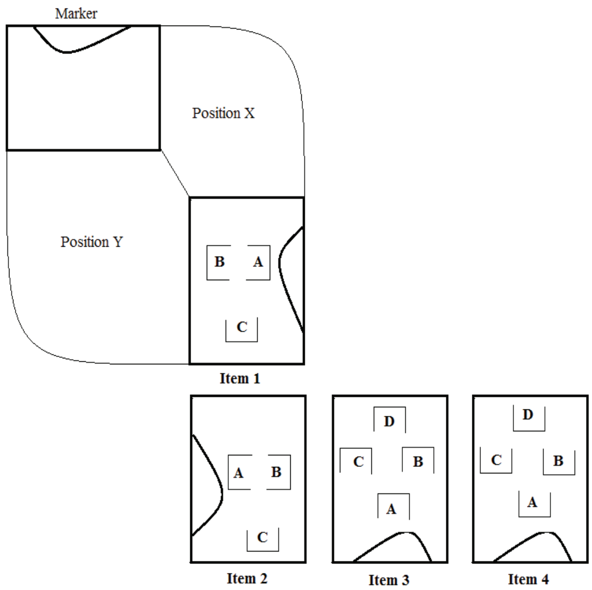

Figure 6. Spatial task

There were four different items with increasing complexity. The simplest item had three houses with no rotation required. The second demanded a rotation of 90º and an inversion of the left-right and front-back orders of the houses. The third and fourth items had four houses and both required 180° rotations and inversions of the left-right and front-back orders. When solved individually, children were oriented to move to the opposite side of the cardboard after the completion of each item to check whether or not they wanted to make changes to their villages. This part of the procedure generated an intra-individual cognitive conflict, as the child could look at the same village from different perspectives (Doise & Mugny, 1984). The same four items and instructions that were used in the individual condition were also applied in the cooperative condition. Children were therefore placed in different face-to-face positions (position X and position Y in Figure 6), so that they were looking at the same village from different angles (Doise & Mugny, 1984). To make sure that one child would not act alone, the cooperative condition operated with interdependent resources (Busch & Butera, 2004), so that each child received only a certain number of houses (either one or two) and were only allowed to touch and move their "own" houses. To move the each other's houses, children had to ask the partner, which consequently increased the chance of creating a socio-cognitive conflict and discussion within the dyad. Children were not told that their partner had a different point of view, and they were not asked to take the other's perspective; the researcher simply emphasized that they should work together to find the solution to the problem. By not making an explicit perspective-taking request we could analyze the children's spontaneous propensity to take the other's knowledge into consideration when faced with a disagreement.

6.4 Measures and scoring

6.4.1 Paper I

For the purpose of Paper I, investigating the role of ToM for children's performance in a cooperative spatial transformation task, we used a short version of the TEC and the TMT in order to create a composite score of ToM. Giménez-Dasí, Pons, and Bender (2016) have also combined these two tests to obtain a broader measure of ToM. However, these authors used a short version of the two tests by reducing the number of items and keeping all the components. We have chosen to reduce the number of components as more items per component should be more reliable than fewer items across several components. Thus, based on the review of the literature which focuses on ToM as an understanding of multiple concepts rather than a single task paradigm (e.g. Blijd-Hoogewys, Geerte, Serra, & Minderaa, 2008; Pons et al., 2004; Wellman & Liu, 2004), we selected components that did not overlap and that represented different levels of difficulty. The ToM measure was therefore composed of perspective taking (3 items), understanding of false-belief (3 items), understanding of second-order false belief (3 items), recognition of basic emotion (5 items), understanding of the impact of situational variations on emotions (5 items), and understanding of desire-based emotion (2 items). This choice warranted the inclusion of both visible or non-reflective dimensions of the mind and more invisible or reflective dimensions of the mind (see Pons et al., 2009). The final score was calculated by summing the number of correct items, therefore ranging from zero to 21.

The performance on the spatial transformation task was based on the same scoring method used in the original work of Doise and Mugny (1984) and it was applied for both the individual and the cooperative conditions. The children first got a spatial score for each item of the spatial task. Children showing no compensation (NC) got 0 points. They did not manage to mentally rotate the cardboard and just reproduced the perceptual tableau that they were able to observe without making any inversion regarding the position of the houses. Children who displayed partial compensation (PC) received one point, meaning that they achieved one of the inversions required, either the right-left order or the front-back order, but not both. Children who demonstrated total compensation (TC) got two points, and this involved correct transformation of both dimensions (left-right and front-back) simultaneously. Subsequently, in both conditions, a total sum score was calculated from the points on the four items, therefore could vary from zero to eight in each condition of the spatial task. Because two dyads did not reach an agreement regarding the resolution of the problem, each child in the entire sample, rather than each dyad, received an individual score for their performance. Nevertheless, the score in the cooperative condition represents the result of the social interaction.

6.4.2 Paper II

For the purpose of Paper II, investigating the extent to which EU explains children's performance in a cooperative sensorimotor task, children's understanding of emotions was measured by all items in the TEC (Pons & Harris, 2000). Children got one point for each correct item with a final score varying from zero to 21.

Task performance on the sensorimotor task represented how close to the end of the labyrinth the children could get. The scoring method was the same in both conditions. First, we calculated the sum of the number of the last hole reached in each level, ranging from zero to 38. In the cooperative condition, all children played the four levels, but in the individual condition, children would stop playing the game when they failed to complete one of the levels. Thus, the number of levels played in the individual and in the cooperative conditions was not always the same. To make them comparable, we calculated the ratio of the last hole reached in each condition by dividing the child's score by 38 (the total number of holes in the game). Thus, the performance in the individual and in the cooperative conditions could vary from zero to one.

6.4.3 Paper III

The same ToM and spatial performance measures used in the study presented in Paper I were used for the study presented in Paper III, which aimed to investigate the impact of ToM on children's attitudes towards another's perspective in the cooperative spatial transformation task. However, we increased the variability in the task performance by adding different weights to the different levels of complexity by multiplying the score in each item according to the degrees of rotation: The score on item 2 was multiplied by 9 (90º), and the scores on items 3 and 4 by 18 (180º). Subsequently, the total sum score calculated for the four items could vary from zero to 92.

In addition, we developed a measure to assess children's attitudes towards another's perspective during socio-cognitive conflict. This categorization followed two main steps. First, based on the work of Zapiti and Psaltis (2012) on the same "Reconstruction of the village task", socio-cognitive conflicts were identified when the child disagreed with the strategy already exhibited by the partner, for example by picking up a house already placed by the other child, changing its spatial orientation, claiming that the placement was wrong or proposing a new solution. In the second step, we analyzed how children responded to each of the socio-cognitive conflicts by coding their attitude toward the partner's conflicting idea. The coding system used in the present study was both data-driven and inspired by previous studies of socio-cognitive conflict (Gauducheau & Cuisiner, 2005; Howe, 2009; Johnson, Johnson, & Tjosvold, 2006). As a result, the two main exclusive categories proposed here represent the child's response to the perspective of the partner when confronted with divergent knowledge: 1) rejection – "I am right, you are wrong" reasoning; 2) Openness – "I see your point" reasoning. Responses that did not fall into these main categories were coded as "other". See Table 2 for a detailed description and examples of each category. Therefore, the categories do not represent children's levels of argumentation or whether or not children ended up in a mutual agreement. These broad categories were chosen to encompass what Johnson and colleagues (2006) have called unfreezing the cognitive process, i.e.: whether or not the child was more rigid in his/her own position or more receptive to the positions of others.

Table 2 *Codes of child's attitudes toward another's perspective*

Child's response to the other's perspective	**Definitions**	**Examples**	
		Non-Verbal	**Verbal**
1. Rejection	Child demonstrates rigid adherence to the original position by ignoring partner's comment and promptly rejecting the other's suggestion.	Child keeps the house where he/she had placed it before	"No. It is not here"
2. Openness	Child acknowledges the suggestions of the partner, by approving it or by giving explanation for an alternative solution.	Child goes along with what the partner suggested and turns the house towards the lake	"Yes, I see, but we should look to the lake, right?"
3. Other	Other behavior that does not fall into any of the categories above.		

The coding was conducted for each interactional sequence. When child A disagreed with child B, we first coded how child B reacted to this divergent opinion, and then how child A responded. The coding continued until the dyad had explicitly demonstrated an agreement about the position of the house(s) or until the children changed the topic of the discussion (e.g., when they started talking about the position of another house). A second coder, who was ignorant of the study aims but had experience in analyzing social interaction through video-recordings, coded 31.25% of the data (10 dyads) independently. The second coder was first trained through a pilot coding of 3 dyads, ensuring that the distinction of the categories and the structure of the task were well understood. Reliability was measured in terms of the frequency of each attitude per child during the interactional sequence. Because this measure is a continuous variable, Pearson correlation analyses were performed to assess inter-rater reliability (Gwet, 2014). There were large positive and significant correlations between the codings of the two coders for the rejection attitude ($r = .82, p < .000$), and for the openness attitude ($r = .83, p < .000$). Due to some variation in the duration of the interactions, the proportion of each type of attitude, rather than the raw score, was used to test our hypotheses. Thus, after summing the frequencies of each attitude, the raw score was divided by the number of total attitudes displayed by the child during the task (the sum of the occurrences of "rejection", "openness", and "other"), therefore varying from zero to one.

6.5 Statistical analyses

SPSS Statistics 22.0 was used for all analyses. Due to the cross-sectional correlational design of the studies, we have tested the main hypotheses through correlation and regression analyses, while analyses of variance were essentially used to run preliminary analyses regarding age and gender.

6.5.1 Analysis of variance

As it is suitable to assess mean variance between different groups (Field, 2009), analyses of variance (ANOVA) were applied for all preliminary analyses evaluating children's performances in the different measures with regard to their age and gender, as well as with regard to the condition of the spatial and sensorimotor tasks (individual versus cooperative).

In all the three studies, two-way between-groups ANOVA were used for assessing the variance on the TMT/TEC scores by age and gender. We chose Two-way ANOVA because it brings the advantage of testing the main effect of each independent variable, as well as the possibility of interaction effect between them. This allowed us to test whether the effect of one variable (age) changed as a function of the second independent variable (gender). For the same reason, two-way between-groups was also employed in Paper III to assess the mean variance on the attitude toward another's perspective between age groups and gender.

A mixed between-within-subjects ANOVA were used to assess the performances in the spatial transformation (Papers I and III) and in the sensorimotor tasks (Paper II). In this test we could combine the analysis of two independent variables being between subjects and the other a within-subject variable. We therefore could assess task performance differences by age and gender (comparison between different groups of participants), by also including the mean difference between the individual and the cooperative conditions (comparison of the same participants across different situations).

6.5.2 Correlation analysis

Because we assessed relationships between different continuous (task performances) and dichotomous (age groups and gender) variables, Pearson product-moment correlation coefficient (r) was suitable to examine correlations in our studies. Bivariate correlation between two variables (zero-order correlation), and whether the correlation of two variables changed when controlling for another variable (partial correlation) were calculated. First, this allowed us to examine whether individual differences in ToM were related to children's performance in the cooperative condition of the spatial and sensorimotor tasks. Second, based on prior research (Pons et al., 2009; Pons et al., 2004; Psaltis & Duven, 2007; Satta et al., 2017), it was expected that both ToM and performances in the spatial and sensorimotor tasks would be related to age, making it crucial to control for this third variable. In addition, because the results about the effect of gender on sensorimotor performance in cooperative conditions are mixed (Voyer, Voyer, Bryden, 1995; Yilmaz, 2009), gender was also included in the partial correlation analyses. Specifically, in Paper I partial correlation analysis was used for investigating the relation between ToM and performances in both conditions of the spatial task (individual and cooperative), when age and gender were taken into account, while in Paper II, partial correlation analysis examined the associations between children's EU and their performances in both conditions of the sensorimotor task (individual and cooperative), while controlling for age and gender.

6.5.3 Multiple regression analysis

Multiple regression analysis was particularly appropriate to address the main question of this thesis about the degree to which scores on ToM/EU tasks could explain the way children interact in problem-solving and their cooperative performance when the model also includes other variables such as age, gender and individual performance on the tasks. It allowed us to assess how much variance in the outcome could be accounted for by the variables included in the model as a whole, and the relative contribution of each of the variables that make up the model (Field, 2009), therefore providing a more sophisticated exploration of the relationship among a set of variables. Standard (or simultaneous) regression was applied in Paper I, and the hierarchical (or sequential) regression in Paper II and III. Whereas in the simultaneous regression all independent variables (predictors) are entered at once in the model, in the hierarchical regression, the predictors are entered in steps in a sequence decided by the researcher and guided by theoretical/empirical reasons. In the hierarchical procedure, each predictor is assessed in terms of how much variance explained it adds to the model, when controlling for the other variables.

For the purpose of Paper I, the predictive value of age, gender, spatial performance in the individual condition, and scores in the ToM tasks for the performances on the spatial task in the cooperative condition were examined through simultaneous regression analysis. Although we foresaw a significant impact of age and individual performance on the spatial task, the perspective taking demanding of the spatial problem could also be a reason to enter the scores on ToM tests at the first step. Thus, we chose this method because we had no theoretical basis for considering any variable to be prior to any other.

For the purpose of Paper II, hierarchical regression analysis was used to examine the contribution of the TEC scores in explaining the variance in the performance in the cooperative condition of the sensorimotor task, when age, gender and performance in the individual condition were taken into account. Age, gender, and scores in the individual condition were entered at Step 1 because previous studies have shown a clear impact of age, gender and individual sensorimotor skills on peer action coordination (e.g. Haddad et al., 2012; Satta et al., 2017). Contrary to this, we have few studies showing the relation between EU and action coordination in peer interaction. Hence, although we had a small set of predictors, we had theoretical and empirical reasons to use hierarchical regression as there was an expectation about which predictors would impact the dependent variable. Consequently, we could obtain clear evidence of how much additional variance might be accounted for EU after entering the TEC scores into the equation at Step 2.

For the same reason as Paper I, in Paper III we also used two independent simultaneous regression analyses to test whether age, gender and ToM predicted the attitudes of rejection and openness when children faced socio-cognitive conflicts in the cooperative condition of the spatial task. Nonetheless, due to the results obtained in Paper I, we had empirical reasons to run a hierarchical regression analysis when the dependent variable was the performance in the cooperative condition of the task. Age, gender, scores in the individual condition of the spatial task, and ToM were entered at Step 1, and the attitudes of rejection and openess were entered into the equation at Step 2. Through this procedure we could assess how much additional variance the model could explain when the attitudes toward another's perspective in social interaction were entered into the equation.

7 Main findings

7.1 Paper I

The goal of this study was to investigate: (1) whether children improve their performance when resolving a spatial task with a peer; and (2) whether ToM affects performance in the cooperative condition of the spatial task. There was a significant performance improvement when children resolved the task cooperatively, regardless of their gender and age. Figure 7 summarizes the main finding of this study: a positive correlation between ToM and the performance in the cooperative condition, even when we controlled for age and gender. The regression analysis showed that age, gender, performance in the individual condition and ToM significantly explained 20% of the variance in the performance in the cooperative condition, with only ToM having a unique contribution in explaining children's performance. In addition, ToM was also positively associated with the performance in the individual condition. The findings suggest that ToM might be an important socio-cognitive mechanism underlying children's cognitive performance on spatial transformation tasks.

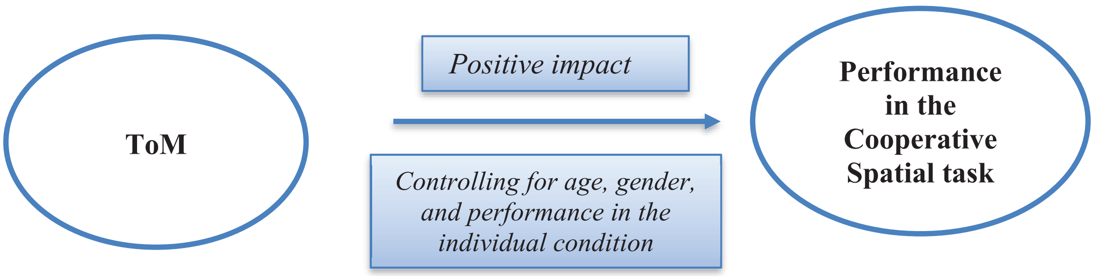

Figure 7. Main finding Paper I

7.2 Paper II

The goal of this study was to investigate whether Emotion Understanding (EU) explains performance in a cooperative sensorimotor task. Notwithstanding children's age and gender, they performed better on the task when they played the game in cooperation with another child. Figure 8 summarizes the main finding of this study: a positive relation between EU and children's performance in the cooperative condition. However, no association between EU and performance in the individual condition was found. Before taking EU into account, 38% of the variance in the performance in the cooperative condition was significantly explained by age and performance in the individual condition. When EU was taken into account it explained an additional 5% of the variance, showing that understanding emotion was a significant predictor of the performance in the cooperative condition of the task, even when age and performance in the individual condition were taken into consideration. The results therefore suggest the existence of emotional mechanism underlying performance in a cooperative sensorimotor task

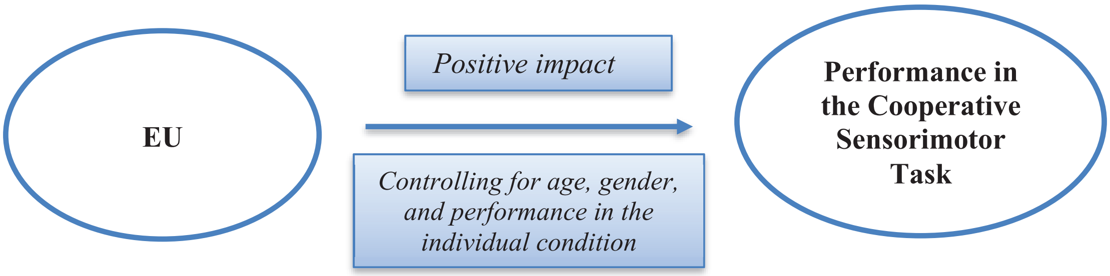

Figure 8. Main finding Paper II

7.3 Paper III

The main goal of this study was to investigate: 1) whether children's ToM can explain their attitudes toward another's perspective when they are faced with socio-cognitive conflicts, when controlling for age and gender; and 2) to what extent ToM as declarative knowledge (ToM standardized task performance) and ToM as procedural skill (attitude toward another's perspective during socio-cognitive conflict) might account for children's performance in the cooperative spatial task. Older children had a more open attitude toward the other child's perspectives than younger children, while younger children displayed more rejection toward the other's perspectives. Figure 9 summarizes the main findings of this study. Children with higher ToM took more often the other child's point of view into account when faced with conflicting ideas, whereas lower ToM predicted children's tendency to reject the other child's viewpoint. The attitudes of rejection and openness explained an additional 8% of the variance in the performance in the cooperative condition of the task after controlling for age, gender, performance in the individual condition, and ToM. Higher levels of ToM and lower frequency of rejection during socio-cognitive conflict were the best predictors of children's performance in the cooperative spatial task, even when controlling for age, gender and performance in the individual condition.

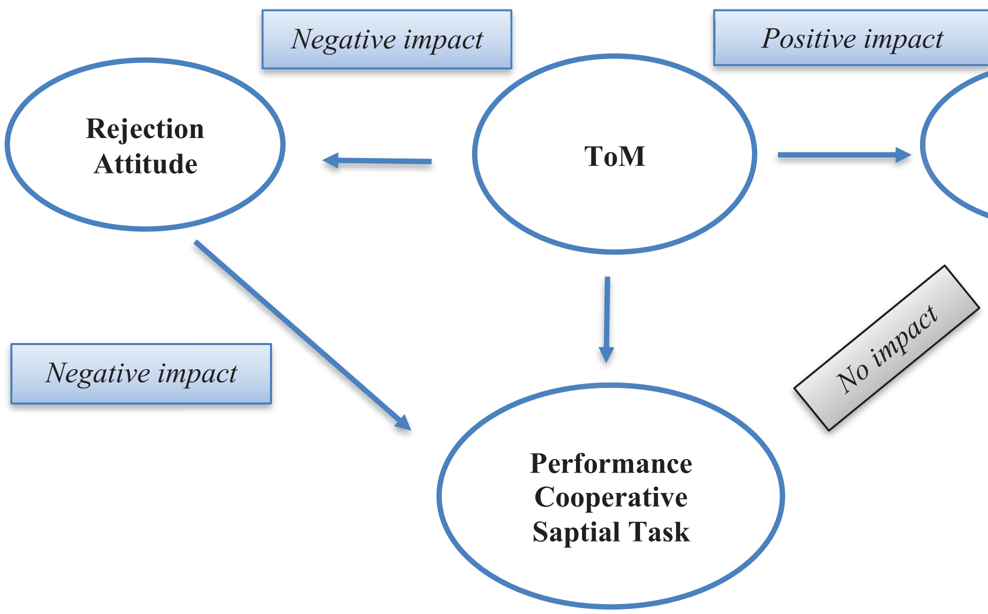

Figure 9. Main findings Paper III

8 Discussion

The main aim of this thesis was to investigate the impact of ToM on the way children interact and their performance in cooperative problem-solving tasks. We found a positive association between higher levels of ToM and higher performance in the cooperative condition of both the sensorimotor and spatial transformation tasks. In addition, lower ToM predicted more rejection attitude toward another's perspective during socio-cognitive conflicts in the cooperative spatial task, whereas higher ToM predicted more openness to the other's point of view. We will discuss and interpret the main findings by arguing for two core ideas: 1) That ToM is one of the socio-cognitive mechanisms underlying cooperative problem-solving in peer interaction; and 2) that when children are taking the partner's perspective into account during such cooperative problem-solving this is done by the use of an integrative system encompassing ToM as declarative knowledge and ToM as a procedural skill. We will also raise some methodological considerations, as well as limitations and prospects for future studies.

8.1 *When* and *how* two minds work better than one: ToM as a socio-cognitive mechanism underlying cooperation

Our main results revealed that ToM positively impacts cooperative problem-solving in two different and complementary ways: 1) Through its impact on the cognitive outcomes of the cooperative tasks, i.e., children's ultimate performance in the sensorimotor and the spatial transformation tasks; and 2) through its impact on the process of cooperation, i.e., children's attitude to another's perspective when facing conflicting ideas during problem resolution. In this section, we will discuss how these results suggest that ToM is one of the socio-cognitive mechanisms underlying cooperative success in peer interaction; and how understanding mental and emotional states and processes is crucial in situations when two minds work better than one in resolving cognitive problems.

Performance improvement in a wide range of cognitive problems when children work together with a partner is well documented in the cooperative learning literature (Doise & Mugny, 1984; Satta et al., 2017; Sommet et al., 2015; Zapitis & Psaltis, 2012). In our studies, we found a "cooperation benefit" in both the sensorimotor and in the spatial transformation problems. It has been shown that many factors contribute to enhance cognitive performance in cooperative tasks, such as different levels of expertise on the task, the occurrence of socio-cognitive conflicts, quality of verbal discussion, and imitative strategy (e.g., Azmitia, 1988; Butera et al., 2011). By providing empirical evidence for the role of ToM in explaining performance in cooperative tasks, our results extend the spectrum of possible answers to the seminal question "when are two heads better than one?" (Azmitia, 1988). Children seem particularly competent to take advantage of the cooperative situation when they can understand each other's minds in terms of beliefs, perspectives, desires and emotions. This is supported by the fact that ToM significantly predicted children's performance in the sensorimotor and in the spatial transformation task, even when age, gender and the children's performance in the individual task condition were taken into consideration. The findings, therefore, point to ToM as one of the socio-cognitive mechanisms promoting better cognitive outcomes in interactive contexts: the better the child is at theorizing about cognitive and emotional states and processes, the better he/she mentally rotates the objects while taking the spatial perspective of another child; and the better he/she adjusts his/her actions to those of another child in a sensorimotor task. Although the cooperative condition demanded similar cognitive skills (spatial transformation or sensorimotor skills) as in the individual condition – which explains the positive relationship between the performance in the two conditions of both tasks – the child's mastery on the task was not enough to explain how well they succeeded in the cooperative condition. Actually, in the spatial task, the effect of the performance in the individual condition even disappeared when ToM was taken into consideration. This essentially means that performance in cooperative problems does not only change as a function of the child's age, his/her individual mastery of the task itself, and improvement in other cognitive abilities such as language and executive functioning, as reported by others (e.g. Doise & Mugny, 1984; Zapiti & Psaltis, 2012; Satta et al., 2017), but also due to ToM competences.

Why would understanding mental and emotional states and processes be advantageous for children in a cooperative situation? It seems that it is the social nature of the cooperative condition, which requests adjustment, coordination and collaboration, that explains the impact of ToM on the ultimate task performance, regardless of whether the cognitive demand of the task is more mentalist (spatial task) or more motoric (sensorimotor task). In the individual condition of the spatial task, the problem centered around object-based transformations, while in the cooperative condition the children needed to go beyond their own spatial visualization and deal with another's spatial perspective, i.e., to manage the projection of relationships between objects while coordinating different viewpoints with the other child. In the individual condition of the sensorimotor problem, the task required hand-eye and intra-individual bimanual action coordination, while in the cooperative condition each child also needed to employ interpersonal coordination by adjusting his/her own movements to those of the other, essentially requiring the coordination of different visual perspectives. This argument is corroborated when looking at the association between ToM and children's spatial and sensorimotor performance in the individual condition, as no relation between EU and child's performance in the individual condition of the sensorimotor task was found. This could possibly be explained by the fact that, although playing the labyrinth ball game alone was itself fun and exciting, potentially eliciting different types of emotions, we are more prone to talk and understand our own and other's emotions in social interaction than in individual contexts. Cummins, Piek, and Dyck (2005) also found that school-aged children with deficit in motor coordination were less competent in emotion recognition but it did not impact their ability to understand emotions (e.g., Barriol, Garitte & Pons, 2013; Piek et al., 2008 for similar results). On the contrary, in our first paper, ToM – including the understanding of cognitive and emotional states and processes – was associated with spatial transformation even in the individual condition. Two interpretations might explain the discrepancy between the results of the spatial and sensorimotor tasks with regard to the impact of ToM on the performance in the individual condition. First, in investigating ToM in relation to spatial abilities we used a composite score that also included the understanding of beliefs and perspectives; and second, when resolving the spatial task alone children had to visualize the houses in different positions by taking the lake as a reference. While the mental rotation in the spatial task demanded perspective taking even in the individual condition, the sensorimotor task in the individual condition was essentially motoric. However, it is noteworthy that, even in the spatial task, the relation between ToM and cognitive performance was stronger in the cooperative condition compared to the individual one. Taking altogether, this suggests that it is the cooperation that builds on ToM, whatever the nature of the task (e.g. mental x motoric).

In order to address how exactly ToM helps children work together, the third paper explored not only the impact of ToM on the performance in the cooperative condition, but also the ways in which children interact when taking the perspectives of another child into consideration during socio-cognitive conflicts. This study particularly showed that children with higher ToM were also those who more often took the other's perspective into account when resolving a disagreement with the other child ("I see your point" reasoning), whereas children with lower ToM were more likely to promptly reject their partner's propositions for a problem solution ("I am right, you are wrong" reasoning). This demonstrates that the attitude toward another's viewpoint during socio-cognitive conflicts varies not only as a function of age, but also as a function of ToM. The results also showed that higher levels of ToM and lower levels of rejection during disagreement were among the best predictors of children's performance in the cooperative condition of the spatial task, even when controlling for age, gender, and spatial performance in the individual condition. The negative impact of rejection on task performance is comprehensible as, by rejecting another's viewpoint, knowledge exchange between partners becomes limited, therefore compromising the potential benefit that cooperation has on cognitive outcomes (e.g., Doise & Mugny, 1984; Sommet et al., 2015; Tversky & Hard, 2009; Zapitis & Psaltis, 2012),

Therefore, the main findings of Paper III advance our knowledge of the socio-cognitive mechanisms underlying the emergence of a constructive conflict resolution essential for cooperation (e.g., Gauducheau & Cuisinier, 2005; Howe, 2009; Sommet et al., 2015). When children consider another's understanding of the problem, they reveal their sense of a shared goal, which is necessary to work cooperatively (Warneken, Grafenhhain, & Tomasello, 2012). By seeing the other's viewpoint as a valid stand point, they can unfreeze their cognitive process (Johnson et al., 2006) and thereby disengage from their own perspective by adopting a more receptive and open attitude toward another's point of view. On the other hand, immediate rejection of the other's proposition does the opposite by impeding the activation of an open and curious attitude toward the partner's perspective, and by creating barriers to use the other person's knowledge and intentions to resolve the problem, potentially creating a sense of competition (Darnon et al., 2002; Sommet et al., 2015). The fact that we made an attempt to control for such competitive behavior by using interdependent resources, and by composing symmetrical dyads in terms of age, gender and knowledge (Buchs & Butera, 2004; Buchs et al., 2004; Sommet et al., 2015), demonstrate that even when the scenario presumably facilitates collaboration, children will not be equally inclined to cooperate.

In sum, the findings inform on how ToM potentially helps two minds work better than one: higher ToM seems to make children more prone to integrate new ideas, and consequently more disposed to cooperate with their partner, thereby activating the "we-mode" (Galloti & Frith, 2013); while lower ToM seems to make children more resistant to the other's perspective and more rigid in their own ideas, consequently reducing the likelihood of creating a joint solution to the problem, creating a sense of "I-mode". In the next section we discuss some theoretical implications drawn from these findings about how ToM as declarative knowledge and ToM as procedural skill form a circular relationship, as well as potential implications for school settings.

8.2 An integrative approach between ToM as declarative knowledge and ToM as procedural skill

Figure 10 presents the definition of declarative and procedural ToM (already presented in Table 1) and the specific measures and findings from our studies: ToM as a declarative knowledge (ToM standardized task performance) was positively related to ToM as procedural skill in the context of problem-solving (openness to another's point of view). The fact that a declarative understanding of cognitive and emotional states made children more capable of taking the perspective of a real partner during socio-cognitive conflicts indicates that the reasoning "If I were in your place, I would see what you see/feel" (Fishbein et al., 1972) – which is explicitly requested in typical ToM declarative tasks – was applied in social interactions where children had to actively use this type of reasoning to adjust thoughts and actions to achieve a common goal.

Figure 10. Declarative ToM X Procedural ToM in cooperative problem-solving

Declarative ToM	
Definition	**Measure**
More or less conscious *knowledge* about the nature, causes and consequences of the mind in the self and others	The child declares the knowledge he/she has about the mind of a story's character
Situation / Content/context free	No conflicting perspectives

Procedural ToM	
Definition	**Measure**
More or less conscious *activities* to recognize, express and control the mind in the self and others	The child acknowledges the partner's point of view during disagreement
Situation / Content/Context specific	Cooperative problem-solving situation

The positive relation between declarative and procedural ToM points in favor of the continuity hypothesis (i.e., that the two types of knowledge are somehow interconnected). Importantly, even though we assessed the impact of declarative ToM on procedural ToM, the findings do not conclude that the continuity works necessarily in this one direction. This is why we used the two-way arrow in the Figure 10. In fact, there is robust evidence that infants can use ToM before they can understand cognitive and emotional states (e.g., Liskowski, 2013). Therefore, in line with Pons & Harris (in press), we make the claim that there is a circular relationship between declarative and procedural ToM. We argue also that this circularity builds on the fact that procedural ToM is context-specific, e.g., in some contexts ToM can be used even when the declarative knowledge is not yet developed (e.g., anticipation of other's actions in infancy), whereas in other contexts one would need a more advanced understanding of the mind to be more efficient in using ToM in social interaction (e.g., taking the other's perspective into consideration in cooperative problem-solving). This implies that knowing and doing operate through a concurrent and bidirectional flow: by recognizing, expressing and controlling the mind in the self and others, children enhance their understanding of the mind at the declarative level; at the same time the development of the knowledge about the mind improves and expands the contexts in which ToM can be efficiently applied. In this case, the trade-off between flexible and efficient ToM proposed by Apperly and colleagues might not necessarily indicate that declarative and procedural ToM represent two uncommunicable systems (e.g., Apperly et al., 2010; Apperly, 2011; Surtees &

Apperly, 2012), but rather that this communication is neither uniform nor context-free.

We argue that the relationship between declarative and procedural ToM is potentially influenced by different contextual factors, such as the age of the participants, the nature of the task – being less or more cognitive and emotional demanding – and the nature of the social interaction and dyad, for instance, child-child versus child-adult, dyadic versus group interaction, symmetrical or asymmetrical dyads with regards to developmental level or gender. For instance, most of the studies conducted by Apperly and colleagues took place in an experimental setting where the participants interacted with an avatar, whereas in our study children interacted with a familiar same-aged partner in their school environment. Symmetry and familiarity with the partners and the place of the interaction might increase the propensity to use ToM, as the demands to deal with an unknown environment are reduced. However, this being said, Lucena (2018) did not find a relation between ToM and 3-5 year old children's strategies to enter in a play already established by two other children in their daycare center. In this case, although children were familiar to each other, they were younger than children of the present study and the interaction was more complex: two children were playing freely and a third child tried to engage in an ongoing play. This latter task, thus, appears to be more cognitive demanding as the child needed to understand the topic of the game, the role of the two other children and potentially anticipate their behaviors in order to find a way to enter the play, interact and be accepted by the group. One potential path for future investigations would be to examine whether the positive relationship found in the present study between having and using ToM abilities remains when children from a wider age range are requested to employ more effortful cognitive processes, such as argumentation and persuasion (Peterson et al., 2018), either in dyadic cognitive tasks or in the same design used by Lucena (2018). In sum, a circular relationship between the two types of knowledge seem more plausible to explain the variety of ways ToM can be requested and used. Within this integrative approach, ToM reaches a broader scope (Astington & Hughes, 2013) as the developmental changes in children's declarative ToM are suggested to be anchored in procedural ToM skills, at the same time as children's procedural ToM skill relies on their declarative ToM achievement.

Finally, considering that the tasks used in our studies had some features that resemble school activities—i.e., the children could communicate freely, they were engaged in a game-playing task, and they were interacting with classmates— some educational implications might be inferred. Programs enhancing ToM in schools might improve cooperative skills typically demanded in educational activities. If it is the case that not only social interaction promotes ToM (e.g., Cutting & Dunn, 2006), but that social interaction also changes due to ToM abilities, it might be important to improve children's declarative ToM by explicitly talking about mental and emotional states during classroom activities, for example, during book reading or by making children explicitly reflect on the other's perspectives during cooperative tasks. Intervention research programs in schools might further elucidate the efficiency of these different types of activities promoting ToM for peer cooperation.

8.3 Methodological consideration

In the following, we will draw some methodological remarks about the study design in terms of the a) representativeness of the sample and the generalizability of the results, b) the challenges in conducting video recording procedure and reliability of the coding system. These considerations are carried out through the lens of reflexivity (Lazard & McAvoy, 2017), which entails the acknowledgment that we researchers are intrinsically involved in the data we generate, the type of analyses we conduct and the interpretations we infer from data.

8.3.1 Generalizability and representativeness

One of the main issues related to the generalizability of the results to other contexts is the sample size, which due to practical reasons was small (e.g., PhD schedule, data collection in another country and observational analysis). Larger sample would have provided more power to detect potential smaller relations, for instance, between EU and individual sensorimotor skills (Paper II), and between the attitude of openness and children's performance in the cooperative spatial task (Paper III). Moreover, our cell sizes were small when running the ANOVA. Thus, increasing the sample size would also be crucial to strength the statistical power of the interaction effect we found, for instance, between age, gender and task condition in both the spatial transformation and sensorimotor tasks. Moreover, it could potentially detect other interaction effects not found in our studies.

The representativeness of our sample is also limited. We assessed a limited age-range (4-9 years of age) in one socio-economic status group (middle class) with a specific cultural background (Brazilian/South American). Selecting participants based on certain criteria such as cultural and family's educational backgrounds has the advantage of providing some control over potential confounding variables (Hultsch, MacDonald, Hunter, Maitland, & Dixon, 2002). There were methodological and theoretical reasons for the criteria we chose for our sampling process. For instance, the language mastery of the researcher and the need to expand studies with the TEC/TMT in South America influenced the context of the data collection. Private schools were preferred over public schools because in Brazil people from middle class usually do not attend public school, and this socioeconomic status would give more reliability to compare our data with previous data using the TEC/TMT, which mainly come from children in Europe and North America. The counterpart of any sample selection criteria is that it creates barriers to generalization. Replicating the present study design in a more diverse context could therefore increase the study generalizability. For example, one could ask whether ToM would impact cooperative problem solving in adolescence/adulthood; or whether we would obtain the same results if children came from public schools in Brazil (working class) or from a non-western society (e.g., Shahaeian et al., 2011; Tang et al., 2017). In addition, in our studies, cooperative problem solving were limited to two specific tasks related to the domains of spatial transformation and sensorimotor abilities. As we previously suggested, it might be that the relations between ToM and cooperative problem solving vary depending on the nature of the task (e.g., mentalistic x sensorimotor), the context in which it takes place (e.g., individual x cooperative), and the dimensions of ToM examined (e.g., cognitive x emotional). Replication of the current study with other types of cognitive tasks, e.g., math problems, would thus enhance the generalizability of our results.

The representativeness of our sample is also limited at the dyad level. We chose to create dyads with children with a very homogenous profile: same age, same gender, as well as similar ToM, spatial transformation and sensorimotor performance. We also had theoretical and empirical reasons for that choice: we wanted to facilitate collaboration by controlling possible factors that could disrupt the flow of the cooperative activity, and previous studies have shown that children tend to interact more cooperatively when in a more symmetric relationship (Buchs et al., 2004; Sommet et al., 2015). However, there are also studies showing that children take more advantage of the interaction when interacting with a more competent partner (e.g., Doise & Mugny, 1984). It would therefore be interesting to examine whether similar results would be found if the dyads were composed asymmetrically (e.g., cross-gender dyads and children with different levels of ToM and spatial/sensorimotor abilities). It would also be interesting to replicate the design by assessing group interaction with more than two children in order to strength the generalization to other interactional contexts.

The trade-off between control and generalizability is also reflected in our choice related to the tasks used and the setting in which the data collection took place. On one hand, the setting was familiar to the children and the tasks resembled activities frequently used in school context; on the other hand, the setting did not really represent an everyday interaction. We chose a quasi-naturalistic environment to obtain a certain level of control over some other potential variables, including the interference from the adults when the children were solving the tasks. At the same time, we also aimed to keep the familiarity with the school environment, which would allow us drawing some conclusions about the implications of our results to the educational field. However, we are aware that transferring the findings of our studies to the everyday life of school settings demands also the replication of the study in a more naturalistic environment, for example, in cooperative problem solving proposed by the teachers in the classroom and problem-solving in a free play group.

8.3.2 Coding system: quantifying qualitative data

It is well known that observing social interaction through video recording improves the quality of the data collection, and consequently the data analysis, by allowing us to play back visual and audio components of the scene under investigation (Pedrosa & Carvalho, 2005; Smith, 2011). However, the dynamics of video recording can also negatively interfere with the results as children can feel intimated and over-evaluated by the camera, therefore potentially changing the way they interact and their task performance. We tried to reduce the potential negative effects of the researcher's presence and the video recording equipment by explaining our role and all the steps involved in the procedure. In addition, we used a tripod to support the camera so we could have some distance from the children, which potentially helped them to be less intimidated. We also allowed children to explore the equipment before starting filming them in case they wanted to; this could make them fulfilling their curiosity and feeling more relaxed in front of the camera.

However, the most challenging aspect of the video recording procedure was related to the process of creating reliable categories to measure what we aimed to measure, i.e., children's attitude toward another's perspective during socio-cognitive conflict.

Reliability

Some strategies were used to strengthen the reliability – the degree of consistency between independent coders regarding the occurrence of the behaviors we were coding. First, I carried out a focused transcription by describing in detail the whole scene in terms of verbal and nonverbal behaviors (Ratcliff, 2003) in order to create a dialogue with the data mediated by the theoretical background, previous studies in the field, as well as the research question of our study (Smith, 2011). This would be considered the qualitative part of the analysis, in which one is open to the details and to the novelty that may arise from the data. Thus, reliability builds on an inward-outward process: In getting closer to the data we could see the specificity of our data in relation to our own research question, whereas in getting distance we consider our data in relation with previous findings. This procedure allowed as to create categories based on our own data and research goals, as well as being motivated by the existing literature.

In the quantitative part of the analysis the two coders fit the behaviors in the pre-defined categories. Even though there was a strong and positive correlation between the two coders, more coders could have either improved the power of our categories or better revealed their potential weakness. Another limitation could be related to generalization: to what extent can our categories be used for the analysis of the interaction in other types of cooperative tasks? The fact that we have chosen broad categories (rejection x openness), instead of in depth categories about children's argumentation/negotiation, might contribute to make our coding system more easily applied in other social contexts. However, broad categories also compromise a more profound understanding of the nuances of children's behaviors in a given interactional situation. The main trade-off in coding and quantifying observational data is often between having a reliable code scheme that can be generalizable, without neglecting the sequential context in which the behaviors are embedded (Bakeman & Quera, 2011). To some extent, our categories overcome these obstacles because although the coding was done for each child separately, it was carried out within a sequential analysis, i.e., whether the child rejected or took into consideration the point of view of the partner. Still, we need to replicate this type of analysis in other cooperative contexts to strengthen the generalizability of the categories used in the present study.

8.4 Other limitations and future studies

Most studies in developmental psychology are still cross-sectional and correlational whereas some are longitudinal or experimental in the strict sense. The studies reported in this thesis can be considered as part of the former and thus have some limitations related to their cross-sectional design. A **longitudinal approach** with a post-test right after the cooperation phase and a follow-up after some months would provide a clearer picture of the short- and long-term effect of the cooperation benefit for cognitive growth (e.g., Doise & Mugny), as well as contribute to our understanding of the developmental changes in the associations between ToM and children's interactions and cognitive outcomes in cooperative tasks. Additional measures to deal with potential **confounding variables**, as well as to have a better representations of the variables having an impact on cooperative problem-solving should also be considered. Taking into account that previous research has shown positive relations between ToM and executive functioning (e.g., Qureshi et al., 2010; Wang, Devine, Wong, & Hughes, 2016), as well as between ToM and language and intelligence (e.g. Harris, de Rosnay, & Pons, 2005), these variables could be included in further analyses. In addition, it is relevant to investigate the role of ToM on **other types of cooperative problems** (e.g., math problems), as well as on non-structured tasks, for instance during free play.

Due to limitations in the time schedule and the fact that coding interaction is a time-consuming procedure, Paper III focused on the social interaction during the spatial task only. It would be highly relevant to examine whether the direct impact of Emotion Understanding (EU) on performance in the cooperative condition of the sensorimotor task remains significant when the abilities to share and regulate emotions while playing the game with a partner are taken into consideration. This would also strengthen our knowledge of EU as a declarative knowledge, as compared to whether this knowledge is applied and, if so, how children use it in social interaction. Would we find a similar pattern as the one found when assessing the interaction in the spatial task? Further investigation of the patterns of conversation that emerged when the child was open to integrate another's knowledge can shed light on the relationship between being receptive to another's knowledge and cognitive performance when working in cooperation. Accordingly, future studies could analyse the social interaction in the spatial transformation task by using more in-depth categories that cover argumentation and persuasion abilities (Peterson et al., 2018). This would further enhance our knowledge of the usefulness of ToM for children's cooperative problem solving and the specific behaviour through which ToM impacts children's cooperation.

Future studies should furthermore address the direction of the relationship between ToM, children's attitudes toward another's perspective and their performance in cooperative problem-solving situations. A **training approach** could be useful for this purpose. For instance, one could implement a pre-test / intervention / post-test / follow-up study where children after being matched for age, gender, cognitive level, ToM level at the pre-test would be divided into different intervention groups: (i) promotion of social interaction, (ii) promotion of ToM, (iii) promotion of both, (iv) promotion of none. A deeper understanding of the mechanisms behind the relationships found in our studies could also arise from studies using mediation analysis. Because previous studies have proposed the existence of indirect links between ToM and social competences (Caputi et al., 2012), and between ToM and school achievement (Lecce et al., 2017), it is relevant to investigate, for example, whether lower ToM relates to lower performance on the cooperative task because low ToM are translated into rigid adherence to one's own point of view when children face conflicting solutions for the problem. Finally, we suggest that research about school readiness (Baptista, Osório, Martins, Verissimo, & Martins, 2016; Wellman, 2018 for discussion) includes cooperation as one learning skill potentially influenced by ToM.

9 Conclusion

The findings of this thesis might contribute to the fields of both cooperative problem solving and social cognition in several ways. First, they suggested that ToM can be acknowledged as one of the socio-cognitive mechanisms underlying cooperation by showing that ToM has an impact on children's (i) attitude toward another's perspective during socio-cognitive conflict, (ii) and the cognitive outcome achieved in cooperation. Understanding mental and emotional states and processes seems necessary (although not sufficient) to cooperate with a partner by facilitating the disengagement from one's point of view and consequently creating a joint solution to a problem. Second, the findings indicated a positive relationship between ToM as declarative knowledge and ToM as procedural skills, and suggested a circular relationship between them. If we, on one hand, become more capable of understanding our own and others' minds by interacting with others, we may on the other hand become more prone and more efficient in cooperating with others by achieving a better understanding of mental and emotional states at the declarative level. Nonetheless ToM may not always be needed and used in social interaction, it appears to be useful and applicable in problem-solving situations among school-age children.

To sum up, we might return to the "sensate" metaphor presented in the introduction of this thesis: To what extent is the "sensate" narrative a fiction or a scientific fact? Although children cannot literally visit others' mind and directly use others' knowledge and actions like "sensates" do, the principle behind the cooperation success among the "sensates" was supported in our results: understanding others' thoughts and feelings is positively related to the effectiveness of children's cooperative problem-solving. "Sensates" appear to portrait a clear (although extraordinary) example of one of the usefulness of ToM in social interaction, and artistically illustrate the importance of being able to understand our own and others' mental world in order to work in a "we-mode". In our studies we could therefore find empirical support that understanding cognitive and emotional mental states indeed make children more prone to take the partner's perspective into account and consequently more efficient in task-relevant cooperation. Effectively, ToM helps children see that they can be wrong even when they think they are right, a realization that aids them working in cooperative tasks through the rationale: *"I am not just a me, but I am also a we".*

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Beyond Conceptual Knowledge: The Impact of Children's Theory-of-Mind on Dyadic Spatial Tasks

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Recent studies show that Theory of Mind (ToM) has implications for children's social competences and psychological well-being. Nevertheless, although it is well documented that children overall take advantage when they have to resolve cognitive problems together with a partner, whether individual difference in ToM is one of the mechanisms that could explain cognitive performances produced in social interaction has received little attention. This study examines to what extent ToM explains children's spatial performances in a dyadic situation. The sample includes 66 boys and girls between the ages of 5–9 years, who were tested for their ToM and for their competence to resolve a Spatial task involving mental rotation and spatial perspective taking, first individually and then in a dyadic condition. Results showed, in accordance with previous research, that children performed better on the Spatial task when they resolved it with a partner. Specifically, children's ToM was a better predictor of their spatial performances in the dyadic condition than their age, gender, and spatial performances in the individual setting. The findings are discussed in terms of the relation between having a conceptual understanding of the mind and the practical implications of this knowledge for cognitive performances in social interaction regarding mental rotation and spatial perspective taking.

Keywords: theory-of-mind, spatial task, cognitive performance, dyadic interaction, children

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INTRODUCTION

The development of 'theory of mind' (ToM), which is the ability to understand the nature, origins, and consequences of the mind (beliefs, intentions, desires, feelings, etc.) in the self and others, has been investigated extensively (e.g., Wellman et al., 2001; Shahaeian et al., 2011; Harris et al., 2016). However, much less is known about the implications of ToM for children's social and cognitive development (e.g., Harris, 2006; Grüneisen et al., 2015). On one hand, recent studies have shown that children's ToM is positively associated with their overall prosocial behaviors and social competences (Caputi et al., 2012; Roazzi et al., 2013; Farina and Belacchi, 2014). On the other hand, the implications of ToM for children's cognition has received less attention and the findings are typically inconsistent (Meins et al., 2006; Veneziano et al., 2008; Guajardo and Cartwright, 2016). Furthermore, albeit it is well documented that on a range of cognitive problems children obtain better performances when solving these together with a partner (e.g., Doise and Mugny, 1984; Tversky and Hard, 2009), to the best of our knowledge, no study has addressed the degree to which individual differences in ToM can account for cognitive problem resolving performances in dyadic settings. In light of the particular reliance on collaborative task performances in the awaiting and modern academic and vocational life, understanding whether collaborative tasks depend on individual abilities can have both practical and pedagogical implications. The present study therefore aims to investigate whether ToM can explain children's performance in a dyadic spatial transformation task which demands the cognitive ability to mentally rotate objects and the coordination of different viewpoints.

When the term 'theory-of-mind' was originally introduced, it was thought of as the competence to attribute mental states to self and others, involving the ability to theorize about others' mind by making inferences regarding mental phenomena (Premarck and Woodruff, 1978). It was thus recognized as a socio-cognitive skill enabling human beings to predict, explain and manipulate others' actions and representations. Traditionally, false-belief tasks, based on the attribution of a mistaken belief, have been central in assessing children's ToM capacities (Wimmer and Perner, 1983). Today, however, it has become more and more common to consider ToM through a wider lens; not only involving the understanding of belief and knowledge, but also encompassing the competence to conceptually understand intentions, desires, and emotions (e.g., Astington, 2001; Wellman et al., 2001; Pons et al., 2004; Dunn, 2006; Shahaeian et al., 2011).

The first studies in the ToM field presented strong evidence for the progress children obtain between 3 and 5 years of age on classical false-belief, appearance-reality, and Level-2 visual perspective taking tasks (Flavell et al., 1983; Flavell, 2004). Albeit important milestones in ToM development occur in the preschool years, the knowledge about mental states continues to increase later on (Flavell, 2004). Research has shown that from infancy to adolescence, ToM develops from a "peripheral and superficial" understanding of rather visible or non-reflective dimensions of the mind (e.g., recognition of basic emotions, understanding of first order false-beliefs and impact of desires on emotions) to a more "central and deeper" understanding of more invisible or reflective dimensions of the mind (e.g., understanding of moral and mixed emotions, of second order false-beliefs and double-bluffs; Pons et al., 2009).

Different directions of research emerged from these early works on trends in ToM development. These studies have been exploring, for instance, antecedents that might contribute to ToM development, intra and intercultural differences, and real world consequences of ToM abilities (e.g., Flavell, 2004; Shahaeian et al., 2011). It is well documented that ToM development depends on many social and cognitive factors, such as language, intelligence, executive function, attachment, and relationships with peers (e.g., Cutting and Dunn, 2006; Pons et al., 2014). Recent studies have also found positive impacts of ToM on social competences at the ages of 3–6 years and psychological well-being at the ages of 8–12 years (e.g., Farina and Belacchi, 2014; Bender et al., 2015). However, the implications of understanding mental states for children's cognition remain unclear. For instance, Veneziano et al. (2008) found that 6–7 year-olds with higher ToM test scores were better able to express epistemic states when they narrated a story. A longitudinal study conducted by Guajardo and Cartwright (2016) tested children at 3–5 years and later at 6–9 years and showed that those who had better understanding of other's perspectives were more aware of their thoughts involved in reading. Lecce et al. (2010) found the same results in a study assessing children between 9 and 10 years of age. On the other hand, Meins et al. (2006) argue that between 6 and 9 years of age, having ToM capacities, measured through conceptual tasks, is different from being able to use it either to narrate a book or to describe friends. Likewise, Guajardo and Cartwright (2016) showed that false-belief understanding did not contribute uniquely to reading comprehension. Together, this suggests at least two gaps when it comes to understand the role of ToM for children's cognition. First, previous studies do not cover a broad measure of ToM that also includes the understanding of desires and emotions; and second, there is still a need to explore other cognitive dimensions potentially influenced by ToM in school-aged children that go beyond the use of mental terms and reading comprehension. One such dimension is the performance on cognitive tasks completed together with peers.

Studies on the impact of ToM on cognitive performances in dyadic interaction are rare, and have especially focused on false-belief reasoning and the process (rather than the outcome) of cooperation. If on one hand it has been shown that ToM works as a powerful social tool that facilitates children's interactions with peers (Moore and Frye, 1991), it remains unclear whether ToM has implications for the cognitive outcome produced in social interaction. For instance, Grüneisen et al. (2015) recently found that 6-year-olds could use first and second order false-beliefs to coordinate actions with peers, showing that recursive mind-reading is an important component of dyadic interaction. Similarly, Flobbe et al. (2008) demonstrated that 8–10 year-olds passing a second order false-belief task are able to apply this when playing a strategic game with a peer. Curry and Chesters (2012) showed that adults scoring lower on a self-report measure of autistic traits and understanding of other's minds were also less successful at coordinating their behaviors with others in coordination games. These researchers subsequently called for studies using a broader range of ToM measures to investigate the impact of children's understanding of the mind on their performances in dyadic settings. Investigating how children solve a spatial transformation task in a dyadic situation might be particularly relevant in this context because it requires both the cognitive ability to mentally rotate objects and the adoption of the spatial perspective of someone else (Kessler and Thomson, 2010).

Spatial abilities comprise activities such as perception of horizontality, mental rotation of objects, or location of simple figures within complex figures (Linn and Petersen, 1985). Specifically, spatial transformation demands the ability to mentally rotating objects and making transformations in their positions based on a specific referential mark (Hegarty and Waller, 2004). Piaget and Inhelder (1952) focused in particular on one aspect of spatial relations called "coordination of perspectives," which refers to the ability to identify the appearance of an object as something dependent on the spatial position from which they are viewed. Based on the classical "three mountains task," they found that children younger than 6 years locate objects with respect to their own points of view, and it is only between 7 and 9 years of age, when children reach the concrete operational stage, that they would be aware of other perspectives than their own and thus deal with an external frame of reference (Piaget and Inhelder, 1952). Spatial relations, therefore, comprises both the cognitive process of projecting relationships between objects, and the social process of understanding the relation between two different perceptions, as exemplified by the "If I were in your place I would see what you see" line of thinking (Fishbein et al., 1972). Flavell et al. (1981) claimed that even under the age of 3, children recognize that people can perceive different objects at the same time (Level-1 perspective taking) but they have difficulties with recognizing that they can see the same object from different perspectives (Level-2 perspective taking). This more sophisticated ability is likely to be developed around 5 years of age. Newcombe and Huttenlocher (1992), for instance, tested children between 3 and 9 years of age and found that children as young as 5 years can take the spatial perspective of others when the task does not entail conflict between two frames of reference.

The Piagetian paradigm presented strong evidence for the role of socio-cognitive conflicts on the development of coordination of perspectives. In the "three mountains task," children have to visualize themselves in a different position and these conflicting representations within the individual promote a breakdown in the cognitive equilibrium that boosts a reinterpretation of the object (Zapiti and Psaltis, 2012). However, in the "three mountains task," the perceptions were not confronted by someone else. Doise and Mugny (1984) contributed enormously to this issue by considering the spatial coordination not only as an intra-individual process but also as an inter-individual one. Based on a critical review of Piaget and Inhelder's (1952) work, they proposed a series of experiments where the coordination of real viewpoints could take place. They tested children between 5 and 8 years of age in a spatial transformation problem called "The reconstruction of the village task," involving both an individual and a dyadic condition. The findings demonstrated a positive impact of peer collaboration on spatial performances as children progressed on the task after they have worked with a partner. The authors argue that when solving a spatial task individually, children have to create intra-individual cognitive conflicts to envision and derive at different solutions, and that this could be less powerful than collaborative settings where the inter-individual conflict and the mutual action context promote subsequent individual progress. Moreover, it could be more effective if each member of the dyad has access to only one part of the resources needed to complete the task (Buchs and Butera, 2004). In a recent study, Zapiti and Psaltis (2012) applied the same "village task" used by Doise and Mugny and tested children between 6.5 to 7.5 years of age to analyze the impact of interaction types on task performance. They found that the pair composition in terms of the children's gender and spatial knowledge affected the expression of point of view and the type of the socio-cognitive conflict that emerged. In a meta-analysis on gender differences in spatial ability, Linn and Petersen (1985) demonstrated how gender relates to spatial performance by showing that males are better than females in mental rotation problems and that the magnitude of this difference is smaller in spatial visualization. The authors also pointed out that the impact of gender might vary depending not simply on the task type but also on the age range of the participants (e.g., Voyer et al., 1995; Yilmaz, 2009).

Thus, even though previous research has demonstrated a positive impact of peer collaboration on spatial performances both with children and adults (Doise and Mugny, 1984; Tversky and Hard, 2009), more studies are needed in order to deepen our understanding of the mechanisms underlying spatial performance in dyadic settings. Because the "village task" demands the cognitive ability to mentally rotate objects and the coordination of different viewpoints, they can be particularly fruitful for the purpose of examining whether broader ToM capacities play a role in children's spatial performance in social interaction. Therefore, the current study addresses two main questions: (1) whether children improve their performance when resolving a spatial transformation task with a partner as compared to alone; (2) and to what extent children's achievements on ToM tasks explain their spatial performances in a dyadic setting. The reasons for focusing on a dyadic setting are twofold: the need to understand potential mechanisms related to individual differences in dealing with spatial problems in social interaction; and the intention to explore the impact of ToM on an advanced cognitive problem, as the performance in the dyadic condition implies not only mental rotation of objects but also the coordination of different hands on spatial perspectives.

One could argue that the village task is a perspective taking problem in itself, so why investigate whether ToM impacts another perspective taking task? First, in this study ToM is not measured based solely on perspective taking ability but as a broad competence including the understanding of beliefs, desires, and emotions (e.g., Shahaeian et al., 2011). Moreover, the "village task" cannot be reduced to its perspective taking dimension. Different from the "three mountains" (Piaget and Inhelder, 1952) and other classical perspective taking tasks, such as the picture and turtle tasks (Masangkay et al., 1974), in the dyadic version of the "the village task" a child can be confronted by the other, so that both children have to deal with two socio-cognitive operations at the same time: (1) the mental rotation of the objects based on an external frame of reference; (2) the perspective of the other child about the position of the objects in relation to the referential mark. When confronted with another spatial representation, the child is challenged to make some changes in his own spatial representation, and as Gopnik and Astington (1988) suggested, it is much easier to ignore your own contradictions than ignore the contradictions between your own representation and the representation of others. Previous studies have shown that adopting others' perspectives remains cognitively demanding even for adults, especially when the perspectives are conflicting (Keysar et al., 2000; Epley et al., 2004; Qureshi et al., 2010). Surtees et al. (2011) tested adults and children between 6 and 11 years of age and found that those who succeed on direct tasks of Level-2 perspective taking showed no evidence of this competence when it was measured in an indirect task where the participants where not explicitly asked about what the partner was seeing. This is also the case with the "village task" in which the participants are encouraged to work together but there is no explicit question about the perspective of the other, though the children need to coordinate their spatial representations to find the solution to the problem. Consequently, we are not applying two simple perspective taking tasks. In addition, the aim is not to assess whether ToM and spatial performance are related competences, but to examine specifically to what extent the performances on classical ToM tasks with different levels of complexity and where the child attributes mental or emotional states to a character in a fictional scenario (without being confronted with another's perspective) can explain the variation in spatial performances in an interactional scenario where the spatial representation of one child can be confronted by that of the other child. In other words, does a broad conceptual knowledge about the mind have implication for children's cognition in the domain of a dyadic spatial task?

In accordance with previous studies, the first hypothesis is that children perform better on the Spatial task in the dyadic setting compared to when doing it by themselves, even when we consider age and gender. Because resolving the Spatial task together with a partner depends on mental rotation of objects and understanding of the other's point of view, the second hypothesis is that children's ToM has a positive impact on spatial performances in the dyadic version of the task, even after taking into account age, gender, and the performance in the individual condition. We expect the results to contribute to the fields of ToM development and social development in at least three ways: by consolidating previous results showing that children take advantage from dyadic setting when resolving a cognitive problem; by originally informing on the role of individual differences in ToM on children's spatial performances in a dyadic setting (illuminating potential mechanisms underpinning spatial abilities in social interactions); and by pointing out a link between conceptual understanding of the mind and its practical implications on children's cognitive performance in the domain of spatial transformation abilities.

MATERIALS AND METHODS

Participants

Initially, 120 parents were contacted through two middle-class private schools in Recife (Brazil). The parents of 90 children (75% of the invited) signed a consent form that informed on the study aims and procedures, allowing their children to be asked to participate. Subsequently, all children invited agreed to participate in the study. The Norwegian Social Science Data Service and the Ethic Committee in Brazil approved the project.

To avoid floor and ceiling effects, children who did not succeed on the simplest item in the individual condition of the Spatial task ($n = 14$), as well as those who achieved the maximum score in the individual setting ($n = 10$) were excluded from the sample (Doise and Mugny, 1984). This ensured that the children could have the same minimum level and that they could also progress on the task. There were equal number of boys and girls among those who failed on the first item and 12 children in the youngest group. Amongst the children who achieved the maximum score, four were girls, six were boys, and all of them were in the oldest group. This is consistent with previous findings (e.g., Doise and Mugny, 1984), as younger children failed more often than the older ones and only children in the oldest group achieved the maximum score. Thus, the final sample included 66 typically developing children (32 boys; 34 girls) between 5 years 7 months and 9 years 8 months ($M = 89.94$ months; $SD = 13.09$ months) with Portuguese as their native language. In order to obtain more variation in terms of ToM competence (the younger group with ToM in progress and the other with well-established ToM), children were divided into two groups according to their age ($n = 36$ in the Younger group: 5;7–7;5 years; $n = 30$ in the Older group: 7;6–9;8 years). Because we wanted to facilitate that children would work together – and because asymmetry in terms of knowledge and gender might create competitive relationship instead of collaboration (Buchs et al., 2004; Sommet et al., 2015) – the dyads consisted of children of the same gender, similar age, from the same classroom, and with similar performances on the individual version of the Spatial task ($SD = 0.84$) and the ToM tasks ($SD = 2.19$). For the same reason, we wanted to ensure that the children in the dyads were neither best friends nor not friends, so that information from the children's ranking of their friends in the classroom was also used when composing the dyads.

Procedure, Tasks, and Scoring

The data collection consisted of three sessions carried out at the children's schools. In the first session, the children were tested individually on the Spatial task. In the second session, the children completed the ToM tasks, and in the third and last session, they participated in the dyadic version of the spatial problem. Each session lasted around 10 min, with an average interval of 15 days between each session.

Spatial Task

Children were first tested individually in an adapted version of the spatial transformation task "the reconstruction of the village," developed by Doise and Mugny (1984) and derived from Piaget's famous "three mountains" task (Piaget and Inhelder, 1952). The task material included a miniature village placed on a model cardboard (50 cm by 50 cm), which was fixed on a table, and comprised a lake (the referential mark) and three or four houses (i.e., based on task complexity, which is described below) with different colors and marked with doors on one side. On a different table, offset 90° from their left, children could see another cardboard also marked with a lake on it. They received three or four houses equivalent to the ones previously placed by the researcher on the model cardboard, and they were instructed to make a similar village. In order to emphasize the referential mark, the experimenter said that if a man comes out of the lake, he would find the houses in the same positions as the ones in the model constructed by the experimenter. Chairs were placed in such a way that the children could not move beyond a limited area.

Figure 1 gives an overview of the task. There were four different items with increasing complexity. The simplest item had three houses with no rotation required. The second demanded a rotation of 90° and an inversion of the left-right and front-back orders of the houses. The third and fourth items had four

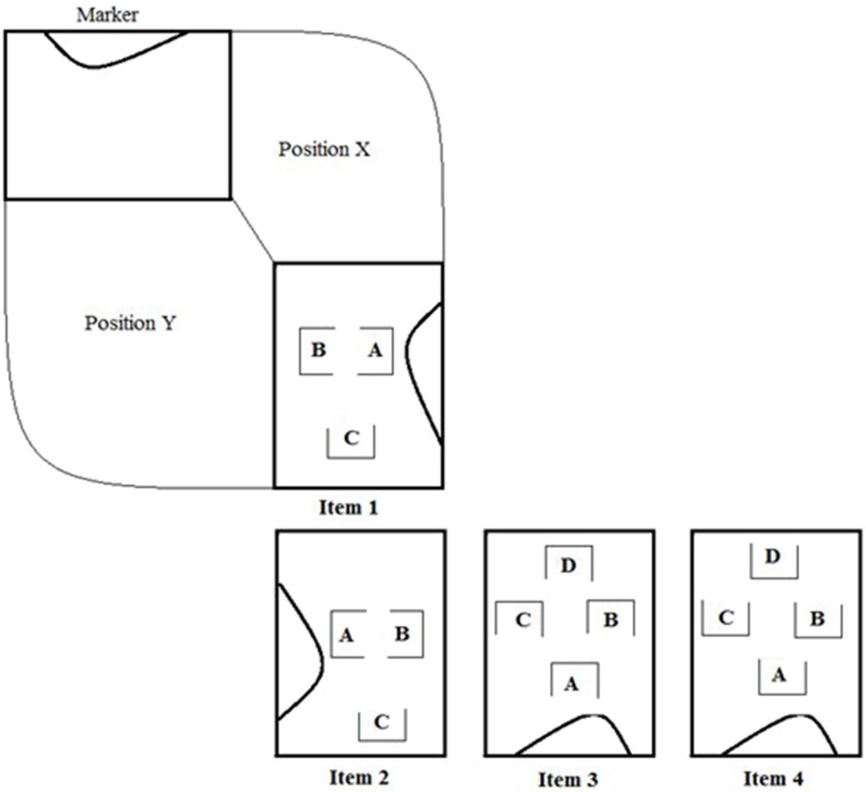

FIGURE 1 | Spatial task.

houses and both required 180° rotations and inversions of the left-right and front-back orders. After the completion of each item, children were oriented to move to the opposite side of the cardboard to check whether or not they wanted to make changes to their villages. When solved individually, this part of the procedure generated an intra-individual cognitive conflict, as the child could look at the same village from different perspectives (Doise and Mugny, 1984).

The same four items were applied in the dyadic condition, but in this situation children were placed in different face-to-face positions (position X and position Y in **Figure 1**). This required them to coordinate their viewpoints to make a copy of a village, which entails an inter-individual cognitive conflict, as it involved looking at the same village from different angles (Doise and Mugny, 1984). To make sure that one child would not act alone, the dyadic condition operated with interdependent resources (Buchs and Butera, 2004), so that each child received only a certain number of houses (either one or two) and were only allowed to touch and move their "own" houses. To move the houses of the "other" child, the children had to convince the partner to do this, providing opportunities for negotiations within the dyad.

The same scoring method, based on the original work of Doise and Mugny (1984), was applied for both the individual and dyadic conditions. The children first got a spatial score for each item of the Spatial task. Children showing no compensation (NC) got 0 points. They did not manage to mentally rotate the cardboard and just reproduced the perceptual tableau that they were able to observe without making any inversion regarding the position of the houses. Children who displayed partial compensation (PC) received one point, meaning that they achieved one of the inversions required, either the right-left order or the front-back order, but not both. Children who demonstrated total compensation (TC) got two points, and this involved correct transformation of both dimensions (left-right and front-back) simultaneously. Subsequently, in both conditions, a total sum score was calculated from the points on the four items, therefore could vary from zero to eight in each condition of the spatial task. Because two dyads did not reach an agreement regarding the resolution of the problem, the score was computed for each child separately in both conditions. Thus, the score in the dyadic setting represents an individual result of the social interaction.

Theory of Mind Task

Children were tested individually for their ToM with items extracted from the Theory of Mind Test (TMT; Pons and Harris, 2002), and the Test of Emotion Comprehension (TEC; Pons and Harris, 2000). Both tests are the result of an extensive review of the developmental literature and of a selection of the most common tasks used to assess children's ToM. Giménez-Dasí et al. (2016) have also combined these two tests to obtain a broad measure of ToM. However, the authors used a short version of the two tests by reducing the number of items and keeping all the components. In addition, they applied the tests in two separate sessions. Because we had an extensive data collection, we applied the TEC and the TMT in the same session which, in turn, required the exclusion of some components. This was a strategy to ensure that the children would be concentrated and motivated during the assessment, and reducing the number of items would still make the tests very lengthy. Moreover, more items per component should be more reliable than fewer items within more components. Thus, based on the review of the literature which focuses on ToM as an understanding of multiple concepts rather than a single task paradigm (e.g., Pons et al., 2004; Wellman and Liu, 2004; Blijd-Hoogewys et al., 2008), we selected components that did not overlap and that represented different levels of difficulty. Children were therefore assessed for their perspective taking (two items in Level 1 and one item in Level 2), understanding of false-belief (three items), understanding of second-order false-belief (three items), recognition of basic emotion (five items), understanding of the impact of situational variations on emotions (five items), and understanding of desire-based emotion (two items). This choice avoided the tests to become too long, but warranted the inclusion of both visible or non-reflective dimensions of the mind and more invisible or reflective dimensions of the mind (Pons et al., 2009). For each item, the examiner showed a drawing while reading a story regarding the depicted characters, and the child was asked to attribute either a cognitive or an emotional mental state to the main character of the story by pointing to one of two or four possible answers. A composite score ranging from 0 to 21 was calculated by summing the number of correct items.

Statistical Analyses

SPSS Statistics 22.0 was used for all analyses in the current study. First, preliminary analyses assessed the performances on the ToM tasks by age and gender through analysis of variance. Subsequently, the first hypothesis was examined through a mixed between-within-subjects analysis of variance to assess the impact of age, gender, and condition (individual and dyadic) on the performance in the Spatial task. To test the second hypothesis, correlation analysis and regression analysis were performed to assess the impact of ToM in explaining the variation on children's spatial performance in the dyadic condition, while accounting for age, gender, and individual spatial performance.

RESULTS

Table 1 shows the performances at the ToM tasks and at the Spatial task (individual and dyadic conditions) by age and gender. An analysis of variance Age X Gender indicated a significant and large effect of age on ToM performances ($F(1,62) = 10.91$, $p = 0.002$, $\eta^2 = 0.15$), but no significant effect of gender or interaction between gender and age. Regardless of gender, older children had higher ToM performances than younger children.

TABLE 1 | Theory of Mind (ToM) by age group and gender and Spatial Performance by condition, age group and gender.

			Spatial performance		ToM
Age group	**Gender**	***n***	**Individual condition *M (SD)***	**Dyadic condition *M (SD)***	***M (SD)***
Younger	Boys	18	3.1 (1.0)	4.7 (2.2)	17.6 (1.5)
	Girls	18	2.5 (0.85)	4.2 (1.3)	17.2 (1.6)
Older	Boys	14	3.1 (1.0)	4.4 (2.7)	18.4 (1.6)
	Girls	16	2.8 (0.71)	6.8 (1.7)	18.9 (1.2)
Total		66	2.9 (0.96)	5.0 (2.2)	18.1 (1.6)

First Hypothesis

An analysis of variance Age X Gender X Condition showed a moderate effect of age ($F(1,62) = 4.72$, $p = 0.034$, $\eta^2 = 0.07$), a large effect of condition ($F(1,62) = 65.29$, $p = 0.000$, $\eta^2 = 0.51$), and no effect of gender on children's performances on the Spatial task. The older children had higher performances ($M = 4.3$; $SD = 1.7$) than younger children ($M = 3.7$, $SD = 1.6$), regardless of condition and gender. Moreover, children had higher performances in the dyadic condition ($M = 5.05$, $SD = 2.23$) than in the individual condition ($M = 2.92$, $SD = 0.96$), regardless of age and gender. There was also an interaction effect of moderate size between age and gender ($F(1,62) = 7.90$, $p = 0.007$, $\eta^2 = 0.011$), indicating that older girls performed better ($M = 4.8$, $SD = 2.3$) than older boys ($M = 3.79$, $SD = 2.5$), regardless the condition. An interaction of moderate effect size between gender and condition ($F(1,62) = 6.62$, $p = 0.012$, $\eta^2 = 0.10$) furthermore showed that girls were better than boys in the dyadic setting, whereas there were no significant gender differences in the individual condition. Finally, a moderate interaction effect was found between condition, age, and gender ($F(1,62) = 6.09$, $p = 0.016$, $\eta^2 = 0.09$), suggesting that older girls obtained higher scores than younger girls and they were better than boys from both age groups in the dyadic version of the Spatial task, but not in the individual condition.

Second Hypothesis

Correlation analysis showed that ToM performances correlated with the spatial performances both in the individual ($r = 0.26$, $n = 66$, $p < 0.038$) and in the dyadic ($r = 0.39$, $n = 66$, $p < 0.001$) conditions, even when we control for age and gender ($r = 0.26$, $n = 66$, $p < 0.038$ and $r = 0.32$, $n = 66$, $p < 0.010$ for the individual and dyadic conditions, respectively). In the regression analysis, the role of age, gender, spatial performance in the individual condition, and scores in the ToM tasks for the performances on the Spatial task in the dyadic condition were examined. This regression model (Multiple $R = 0.45$, $F(4,61) = 3.81$, $p < 0.008$) showed that the predictors explained in total 20% ($R^2 = 0.20$) of the variation in the dependent variable. When examining the impact of the different predictors, ToM ($b = 0.31$; $t = 2.4$, $p < 0.020$), but not age, gender, nor spatial performance in the individual condition, had a significant effect on the spatial performance in the dyadic condition. ToM accounted for 15% of the shared variance ($r = 0.39$) and explained alone 8% ($r = 0.29$) of the variance of the children's performance in the dyadic Spatial task.

DISCUSSION

The goal of this study was to investigate: (1) whether children improve their performance when resolving a Spatial task with a peer; and (2) whether individual differences in ToM affect children's spatial performances in a dyadic setting. In line with prior research (Doise and Mugny, 1984; Psaltis and Duveen, 2007), we found that children improved their performance on the Spatial task when they resolved it together with a partner compared to when resolving it alone. For the first time, this study showed that children's performances in a dyadic Spatial task were predicted by their ToM, even when accounting for age, gender, and the children's spatial performances on the same task in an individual condition.

Spatial Performances Across Age, Gender, and Condition

Confirming our first hypothesis, children performed better in the dyadic compared to the individual setting. This is consistent with the original experiments carried out by Doise and Mugny (1984) and other studies showing that children between 5 and 9 years of age profit from resolving tasks with a partner (e.g., Psaltis and Duveen, 2007; Zapiti and Psaltis, 2012). It has been argued that such results demonstrate that inter-individual conflicts are central for children's cognitive development, and that this is particularly happening when children work on complementary resources to resolve problems (Buchs and Butera, 2004). The current study extends prior results on spatial problems that have reported beneficial effects of social interaction on cognitive performances in samples of older children and adults (Teasley, 1995; Tversky and Hard, 2009). One potential explanation is that the non-verbal and verbal behaviors of the other support the understanding of the objects and their spatial relations, so that the mutual action context promoted by social interaction helps children to (re-)think about the activity from the other's perspective (Tversky and Hard, 2009; Frick and Wang, 2013).

As has been suggested earlier in the field (Piaget and Inhelder, 1952), the effect of age on children's overall spatial performance indicates that spatial ability follows a developmental trend. The absence of an effect of age on spatial performance when children resolved the task by themselves might be related to the way we divided the groups. According to the literature, it is typically somewhere between the ages of 7 (younger group) and 9 (older group) years that children start to imagine an orientation outside their body, and work with relations such as before/behind and left/right (Piaget and Inhelder, 1952; Yilmaz, 2009). The enhanced performance of older compared to the younger children in the dyadic condition could be related to the higher reliance on more advanced social and linguistic abilities in this setting (Siegal, 2008).

The fact that gender had no main impact on children's overall spatial performance contrasts with previous work that found that males perform better than females on mental rotation problems (Voyer et al., 1995; Yilmaz, 2009). However, this gender difference in mental rotation seems to appear from the age of 10, and could possibly be related to boys having more experiences with manipulation of symbolic information than girls by that age. Thus, gender differences may occur as the children gets older, which might explain the interaction effect between age and gender showing that older girls were better than younger boys, independent of the condition. Indeed, the literature suggests that the impact of gender varies according to both age and the type of task (Yilmaz, 2009), which shed some light on the interaction effect between gender and condition, and between age, gender, and condition. Thus, one reason for the gender differences in the dyadic setting may be that this condition depends more on broader social and language skills, which are dimensions where girls and older children typically demonstrate better abilities than boys and younger children (Walker et al., 2002; Siegal, 2008). More research with a larger age range is needed, however, to understand why gender differences appear in different conditions and how they might evolve over time.

The Impact of ToM on Spatial Performances

The impact of age on ToM performances was expected, as previous studies have shown that ToM follows a clear developmental trend, both in boys and girls (e.g., Harris et al., 2005; Shahaeian et al., 2011). The results originally showed relations between ToM and spatial performances, both in the individual and in the dyadic conditions, even when age and gender were taken into account. Moreover, confirming the second hypothesis of this study, ToM had a positive impact on the spatial performance when children worked together, even when we controlled for age, gender, and spatial performance in the individual condition.

The link between ToM and the spatial performance in the individual setting indicates that the abilities to conceptually understanding the mind in terms of thoughts and emotions and to cognitively visualize objects in different positions based on an external frame of reference are related competences. The findings therefore expand previous results by demonstrating that understanding mental states has positive consequences not only on social competences (e.g., Roazzi et al., 2013; Farina and Belacchi, 2014) and the use of mental terms and metacognition (Veneziano et al., 2008; Lecce et al., 2010; Guajardo and Cartwright, 2016), but also on the domain of children's cognition with regard to spatial visualization, which is a spatial transformation where "the positions of objects are moved with respect to an environmental frame of reference" (Hegarty and Waller, 2004, p. 127). In the present study it means that children with higher level of conceptual ToM were better able to mentally rotate the object and correctly transform the positions of the houses by taking the lake as the referential mark.

One could argue that once a relation between ToM and the spatial performance in the individual condition was found, a relation between ToM and the performance in the dyadic condition would be expected. Yet, the performance in the two conditions rely on different levels of spatial skills, as indicated by the findings showing the absence of a relation between the performance in the individual condition (making object-based transformation) and the performance in the dyadic condition (coordinating different perspectives). This is in line with the dissociation between tests of perspective taking and tests of mental rotation reported by others (Hegarty and Waller, 2004). Thus, we could not interpret the correlation between ToM and the performance in the dyadic condition as parallel to the correlation between ToM and the performance in the individual condition. It is also noteworthy that the relation between ToM and spatial performance was stronger in the dyadic compared with the individual setting. Moreover, beyond examining how ToM and the spatial performance in the dyadic condition were related, our aim was to investigate the degree to which ToM abilities could explain variation in the spatial performances in a social interaction setting. It was only ToM that significantly explained the performance in the Spatial task when children worked together, while the children's age or their previous experience with the task did not. This finding therefore suggests the existence of socio-cognitive mechanisms underpinning spatial performance in social interactions.

A comparison of the two conditions of the Spatial task might deepen our understanding on such socio-cognitive mechanism. When resolving the task alone children had to visualize the houses in different positions by taking the lake as a reference. Even when the child changed the position to see the cardboard from a different angle (intra-individual conflict), the task in the individual setting centered around object-based transformations, while in the dyadic setting they needed to go beyond their own spatial visualization and deal with the other's spatial perspective. In fact, the performance in the dyadic condition of the Spatial task seems to be more strongly dependent on the performance on the ToM tests where the child also had to take the mental perspective of the character. Thus, one could argue that a link between ToM and the spatial performance in the dyadic setting would be expected because the Spatial task in the dyadic condition essentially demands perspective taking. Nevertheless, the task in the dyadic condition cannot be reduced to its perspective taking dimension as the children also needed to manage the object-based transformation while coordinating different viewpoints with the other child, which is an advanced form of cognitive problem. In addition, we used a broad measure of ToM that assessed not only perspective taking but also false-belief and emotion comprehension, in which – different from the Spatial task – children's beliefs and perspectives were not confronted by the experimenter or another child. Thus, the main explanation is that the findings add a new factor to the previous results on the reconstruction of the village task (e.g., Doise and Mugny, 1984; Zapiti and Psaltis, 2012) by pointing out that the better the child is at conceptually theorizing about the mind in a fictional scenario in terms of beliefs, perspectives, and emotions, the better he mentally rotates the objects while taking the spatial perspective of a real partner.

The current findings can therefore shed new light on the link between conceptual understanding of the mind and its practical implication for children's cognition, especially for cognitive performance in social interaction. According to Tversky and Hard (2009), seeing another person in a scene near objects can elicit spontaneous perspective taking, which, in turn, create mutual expectations between partners while attempting to coordinate actions, imposed each person to go into multiple levels of perspectives. Nevertheless, Keysar et al. (2000) showed that even adults with high levels of ToM can demonstrate difficulties in applying these abilities to take other's perspective. Accordingly, Samson and Apperly (2010) argue that using ToM could be a cognitively costly process involving the need to resist the interference from the egocentric perspective and to select relevant information necessary for ToM inferences, potentially creating a gap between competence and performance. We should point out some distinctions between the previous and the current findings. Notwithstanding the differences in age ranges, the aforementioned studies focused on perspective taking, while we have assessed a broad measure of ToM. This might suggest that the implication of ToM for children's spatial performances cannot be seen as a uniform fact, as it can vary depending on the age range of the participants, how ToM is measured and what context it is applied in. A broad measure of ToM is potentially accounting for more variability in spatial performances than measures of perspective taking or false-belief alone, especially when the task is spatial and social at the same time (i.e., the village task). Perhaps a broad measure of ToM that includes the understanding of beliefs, desires, and emotions is part of a broader socio-cognitive process underlying spatial and social-perspective taking. In light of findings suggesting that social abilities are related to a more visually driven form of perspective taking (Clements-Stephens et al., 2013; Hamilton et al., 2014), future studies analyzing how children consider the other's point of view while cooperatively resolving a spatial problem may contribute to understanding the extent to which and how ToM, social perspective taking and spatial performance are intertwined.

In sum, our results showed that conceptual competence can account for variation in cognitive performances on a Spatial task in children between 5–9 years of age, and in particularly so when the ToM measure includes different concepts. This does not indicate that we can directly translate ToM competence into spatial performance, and future studies should examine the role of potential third variables, such as language, cooperative behavior, intelligence, and executive functions (Wellman, 2014) to have a more complete picture of the role of ToM on spatial performance. As for now, the findings illustrate that, although not sufficient (Astington, 2003; Samson and Apperly, 2010), higher ToM levels can have positive implications for cognitive performances in terms of mental rotation and spatial perspective taking during peer interaction.

Limitations

Some limitations should be mentioned. A larger sample size would have provided more power to detect significant relations and group differences in the present study. The inclusion of a post-test section (Doise and Mugny, 1984) would inform on possible long-term effects of the dyadic experiences. Future studies could also apply a longitudinal approach to address potential developmental processes. In addition, training studies aiming at strengthening ToM competences might provide stronger evidence of the positive impact of ToM on spatial performances. Inclusion of additional ToM concepts, as well as examination of the contributions of the separate components of the TEC and TMT could also contribute to a deeper understanding of the role of ToM on cognition.

Another limitation is that we did not analyze the interactional processes in the dyadic setting. Zapiti and Psaltis (2012), for instance, showed that what happens in the interaction affects the final spatial performance. In addition, Caputi et al. (2012) underlined that the relation between having and using ToM in social interaction is mediated by social factors. It could be argued that having the same intention toward the task does not specify the kind of social relation children would establish (Thomsen and Carey, 2013) and that different dyadic profiles, either more unilateral/hierarchical or more cooperative could affect performances in dyadic settings (Psaltis and Duveen, 2007). Thus, investigating the process of how children interact and operate with the socio-cognitive conflict could help to better understand how ToM explains the spatial performance in the dyadic Spatial task. Last, but not least, it is not certain that the same results would have occurred in other type of cognitive problem or if the spatial abilities were examined in a non-structured task. Investigating the impact of ToM in everyday interaction could deepen our understanding on the implication of ToM for children's cognition with regard to the nature of the task and the nature of the interaction.

CONCLUSION

Both hypotheses of the current study were confirmed: (1) children performed better in the dyadic setting compared to when doing it by themselves; and (2) children's ToM had a positive impact on the spatial performance in the dyadic condition. Theoretically, these findings add a new aspect to the explanations based on inter-individual conflict and action-based reasoning (Doise and Mugny, 1984; Tversky and Hard, 2009; Zapiti and Psaltis, 2012) by illuminating socio-cognitive mechanisms that link conceptual competence in understanding the mind with spatial performance within interactional settings. The results demonstrate that individual differences in ToM – not only in terms of false-belief or perspective taking, but also in terms of emotion comprehension – impact children's cognition and have to be taken into account in order to get a more complete picture of what promotes spatial performances in social interactions. Hence, three practical implications can be derived from it. First, it implies the need to elaborate more adequate and sensitive measures to grasp the cognitive consequences of ToM in a wide range of interactional contexts. Second, pedagogues might need to consider children's ToM abilities when composing dyads and groups to solve spatial problems in cooperation, as such grouping might yield different outcomes. Finally, the findings suggest that teaching and strengthening of children's ToM competences can have positive impact on children's cognitive performance in important settings, such as in school, at least when it comes to spatial problems. To conclude, the link between what *ToM is* and what *ToM is for* (Liszkowski, 2013) does not indicate that ToM concepts are sufficient to efficiently promote successful cognitive outcome in social interaction (Astington, 2003). However, it shows that having such concepts goes beyond conceptual knowledge and can have practical implications for children's cognition. This study demonstrates how this is the case in the domain of spatial transformation in peer interaction.

AUTHOR CONTRIBUTIONS

KV and FP designed the study. KV coordinated data collection and KV, IZ, EK, and FP contributed to the analysis and interpretation of the data for the work. KV prepared the first draft of the article and all authors revised it critically and approved the version to be published.

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