EXPLORING SOCIAL INFLUENCES ON EXECUTIVE FUNCTION IN PRESCHOOL CHILDREN

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ABSTRACT

The development of executive function in young children is currently a central topic in developmental science. Despite great interest in this area, empirical research examining the influence of social interaction on children's executive functioning is still scarce. The present study aims to fill this gap by addressing how aspects of current and preceding social interactions affect preschool children's executive function performance.

In the first phase of the experiment four- and five-year-old children completed an activity either individually or in collaboration with an experimenter. Following this manipulation, children completed a series of executive function tasks. The first task was a motor contagion task in which children moved a stylus on a graphics tablet while viewing a background video of another person producing congruent or incongruent movements. Children also completed a go/no-go task, a two-choice spatial compatibility task (i.e., a Simon task), and two joint go/no-go tasks in which they essentially shared a Simon task with an experimenter.

The main finding from the motor contagion task was that children who collaborated with an experimenter in the first part of the study were more susceptible to interference from observing incongruent movements produced by their partner from the collaborative activity compared to observing the same movements produced by an experimenter who merely observed the collaboration. In addition, for children in both conditions, the results of the go/no-go and Simon tasks indicated the presence of a joint Simon effect. Specifically, a significant spatial compatibility effect was observed in the Simon task and the first time children completed the joint go/no-go task with an experimenter. Importantly, there was no spatial compatibility effect when children completed an individual go/no-go task. No differences were found for the joint Simon effect related to the social manipulation. The findings are discussed in relation to their implications for our understanding of social influences on children's developing executive abilities.

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CHAPTER 1

INTRODUCTION

Success on most cognitive tasks requires an individual to hold information in mind, to quickly modify attention and action, and to inhibit prepotent responses. These abilities can be classified as working memory, cognitive flexibility, and inhibition, respectively (Miyake et al., 2000). Together, they form the construct of executive function, which enables individuals to override more automatic thoughts and actions and maintain and monitor task performance. Executive function is related to the broader construct of self-regulation, which refers to the control of one's behaviors and emotions (Bronson, 2000).

Executive function undergoes a protracted development with a marked transition occurring in early childhood (Zelazo et al., 2003). Developmental scientists have created a variety of tasks to assess inhibitory control, working memory, and cognitive flexibility in young children. Although some tasks are slightly harder and some slightly easier, there is a progressive shift to better performance between 3 and 7 years of age (Diamond & Taylor, 1996; Garon, Bryson, & Smith, 2008; Zelazo et al., 2003). This shift is thought to be related to changes in the prefrontal cortex which undergoes considerable development during the preschool period (Tsujimoto, 2008).

Longitudinal studies have demonstrated executive function in preschool predicts important outcomes in later childhood and early adulthood. For example, performance on executive function tasks predicts achievement in reading and math in the early elementary years (Gathercole & Pickering, 2000; Ponitz, McClelland, Matthews, & Morrison, 2009) and with better accuracy than IQ (Blair & Razza, 2007). Other work has shown that performance on inhibitory control tasks in preschool is a strong predictor of health, wealth, and aspects of moral decision-making in adulthood (Mischel et al., 2011; Moffitt et al., 2011). Given the link between early executive function and successful outcomes across various developmental domains, there is currently great interest in whether executive function in young children can be improved with training (Bryck & Fisher, 2012; Diamond & Lee, 2011). Existing studies in this area have reported mixed results. A number of interventions have been associated with significant gains in executive function including CogMed computerized training (Holmes, Gathercole, & Dunning, 2009; Klingberg et al., 2005; Thorell, Lindqvist, Bergman Nutley, Bohlin, & Klingberg, 2009), Tools of the Mind (Diamond, Barnett, Thomas, & Munro, 2007), Promoting Alternative Thinking Strategies (PATHS; Riggs, Greenberg, Kusche, & Pentz, 2006), and the Chicago School Readiness Project (Raver et al., 2011; Raver et al., 2008). However, other studies have reported no improvements after training (Farran, Wilson, & Lipsey, 2013) or limited transfer to more ecologically valid measures of executive function (Dunning, Holmes, & Gathercole, 2013; Melby-Lervag & Hulme, 2013; St. Clair-Thompson, Stevens, Hunt, & Bolder, 2010).

One topic that has received relatively less attention concerns the influence of social context on executive processes in children. Indeed, it could be argued that the majority of contemporary empirical work has focused on the child as an isolated individual (Lewis & Carpendale, 2009). This is surprising considering various proposals have emphasized the importance of social factors in the development of executive function (Landry & Smith, 2010; Sokol, Muller, Carpendale, Young, & Iarocci, 2010).

Notably, Vygotsky's (1978) influential theory posited that executive function develops largely through social interaction with caregivers and peers. The present study takes an initial step towards elucidating how social factors influence executive control processes in preschool children. Specifically, we examined how engaging in a collaborative activity versus working alone influenced motor contagion and general response inhibition in 4- to 5-year-old children. We also examined whether the joint Simon effect could be elicited in young children and if the extent of the effect was different for children who had worked collaboratively versus individually. Exploring the short-term effects of social manipulations on executive function performance in young children is currently a limited, yet promising avenue of research (Hala & Russell, 2001; Kidd, Palmeri, & Aslin, 2013; Qu, 2011). The next two sections will review existing research on motor contagion and the joint Simon effect, with a particular emphasis on studies examining how social priming influences adults' performance on motor contagion and joint Simon tasks. The last introductory section will briefly review how different types of social interactions affect adults' executive function.

Motor Contagion

There is a large literature demonstrating that observed actions interfere with the simultaneous production of an incongruent action. This work is linked to theoretical proposals that one's own actions and others' actions are coded in a common framework (Jeannerod, 2001; Prinz, 1997) and neuroimaging research demonstrating that similar neural systems are recruited during action observation and action execution (for a review, see Molenberghs, Cunnington, & Mattingley, 2012). In a commonly used experimental paradigm, participants are instructed to lift a finger (e.g., index finger) while observing a video of another person lifting the same finger (congruent condition) or a different finger (incongruent condition). Relative to congruent trials, reaction times to initiate finger movement are significantly slower for incongruent trials (Brass, Bekkering, & Prinz, 2001; Brass, Bekkering, Wohlschlager, & Prinz, 2000). Another well-replicated finding is that the execution of arm movements in one plane (e.g., vertical) is perturbed by the simultaneous observation of a person producing arm movements in the opposite plane (e.g., horizontal; Bouquet, Gaurier, Shipley, Toussaint, & Blandin, 2007; Kilner, Hamilton, & Blakemore, 2007; Kilner, Paulignan, & Blakemore, 2003). Using a developmentally appropriate version of this task, Marshall, Bouquet, Thomas, and Shipley (2010) found similar interference effects in preschool children. In this study, children were instructed to move a stylus on a graphics tablet in the horizontal or vertical axis while simultaneously viewing a background video of an actor producing congruent or incongruent arm movements. Compared to viewing congruent movements, viewing incongruent movements was associated with significantly greater variability in stylus position in the error axis (i.e., the axis opposite to the axis children were instructed to move in).

In these stimulus-response tasks, poorer performance on incongruent trials is thought to be due to “motor contagion” (Blakemore & Frith, 2005), also commonly referred to as “automatic imitation”, in which observed actions activate matching motor programs in the observer resulting in interference when the observed action is incompatible with the participant’s assigned task. The strongest support for this hypothesis is provided by transcranial magnetic stimulation (TMS) studies that have found observing the actions of others leads to sub threshold activation in the specific muscles that the subjects would use to produce these movements themselves (Clark, Tremblay, & Ste-Marie, 2004; Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995; Gangitano, Mottaghy, & Pascual-Leone, 2001). This hypothesis is additionally supported by several studies that have demonstrated interference is greater when the observed movement is produced by a human compared to a robotic agent (Kilner et al., 2003; Press, Bird, Flach, & Heyes, 2005), and when it follows a biological rather than a mechanical motion trajectory (Bouquet et al., 2007; Kilner et al., 2007).

Influence of Social Priming on Motor Contagion

Particularly important for the current study, there is increasing evidence that social priming modulates adults' unconscious imitation of others' movements (Cook & Bird, 2011; Leighton, Bird, Orsini, & Heyes, 2010; Spengler, Brass, Kuhn, & Schutz-Bosbach, 2010). In an initial study on this topic, van Baaren, Maddux, Chartrand, de Bouter, & van Knippenberg (2003) had participants complete a scrambled sentence task involving either interdependent words (e.g., together, cooperate) or independent words (e.g., unique, individual). Compared to participants primed with independent words, participants primed with interdependent words were more likely to match the movements of a confederate in a subsequent interaction. In a second study, van Baaren and colleagues (2003) found that participants from collectivist cultures that typically have a chronic interdependent self-construal (e.g., Japanese) show more imitation than participants from individualistic cultures (e.g., American). These findings of greater imitative tendencies in more naturalistic settings have been confirmed by a number of studies using automatic imitation tasks (i.e., motor contagion tasks; Cook & Bird, 2011; Cook & Bird, 2012; Leighton et al., 2010; Spengler et al., 2010). In one such study, participants primed with interdependent words were more susceptible to interference from incongruent movements on a stimulus-response task involving hand opening and closing compared to participants primed with independent words (Leighton et al., 2010).

The Joint Simon Effect

In recent years, there has been a trend in cognitive psychology and cognitive neuroscience towards examining how cognitive processes unfold in social contexts (Przyrembel, Smallwood, Pauen, & Singer, 2012). One widely used task in this area is the joint Simon task, a modified version of the standard Simon task, which is a two-choice spatial compatibility task that requires participants to press left and right buttons when the stimulus signaling the action (a left or right button press) appears on the left or right side of a screen. Although stimulus location is irrelevant to the task, it is well replicated that participants are faster to respond when the stimulus and response are compatible (i.e., on the same side) compared to when the stimulus and response are on opposite sides (the "Simon effect"; Craft & Simon, 1970; Simon, 1969). It is generally assumed that slower reaction times on incongruent trials are due to a conflict between two activated responses: The response generated by the automatic activation of the response that corresponds with the stimulus location and the response generated based on the task instructions (De Jong, Liang, & Lauber, 1994; Ferraro, Iani, Mariani, Milanese, & Rubichi, 2011; Lu & Proctor, 1995). When the stimulus and response spatially correspond, there is no conflict, which leads to a faster response.

When the Simon task is changed such that participants have to respond to only one of the two stimuli (changing the task to a basic go/no-go task), the spatial-correspondence effect disappears. There is no spatial dimension and therefore no conflict when the stimulus appears on the opposite side of the response key. However, when two people perform the go/no-go task together, with each person responding to one of the two stimuli, the spatial compatibility effect observed in the standard Simon task reappears (Sebanz, Knoblich, & Prinz, 2003). Since the initial report by Sebanz and colleagues (2003), this so-called "joint Simon effect" has been replicated in dozens of studies. The effect is generally thought to be due to the participants co-representing their partner's part of the task as if they were responding to both stimuli (Sebanz, Bekkering, & Knoblich, 2006a; Sebanz et al., 2003; Welsh, Higgins, Ray, & Weeks, 2007). In support of the co-representation account, studies utilizing electrophysiological measures demonstrate that greater inhibitory control is needed to withhold from responding on no-go trials in the joint (versus individual) condition (Sebanz, Knoblich, Prinz, & Wascher, 2006b; Tsai, Kuo, Jing, Hung, & Tzeng, 2006). In addition, more recent studies have reported motor cortex activation in participants during the joint go/no-go task when it is their partner's turn to respond (Hollander, Jung, & Prinz, 2011; Tsai, Kuo, Hung, & Tzeng, 2008).

Social Influences on the Joint Simon Effect

Initial interpretations suggested the joint Simon effect was specifically social in nature (Knoblich & Sebanz, 2006; Sebanz et al., 2006a; Tsai et al., 2008), but a recent study suggests it may be partially accounted for by perceptual processes in which one's actions are coded as to the left or right of an alternative event, regardless of whether that event involves a social partner or a nonsocial salient object (Dolk, Hommel, Prinz, & Liepelt, 2013). While this suggests a role for bottom-up processes on the joint Simon effect, many studies have found social factors modulate the effect in a top-down fashion. For example, knowledge of a co-actor is sufficient to produce a joint Simon effect even if they cannot be seen (Tsai et al., 2008; Vlainic, Liepelt, Colzato, Prinz, & Hommel, 2010). Other work has shown that the interpersonal relationship between the co-actors can exert a significant influence on the magnitude of the spatial compatibility effect in the joint context. Hommel, Colzato, & van den Wildenberg (2009) observed a joint Simon effect when participants performed the joint Simon task alongside a friendly, but not an antagonistic, co-actor. A related study found a joint Simon effect when participants were dependent on their partner's performance to receive a monetary award, but this effect disappeared when the two participants were competing for the reward (Iani, Anelli, Nicoletti, Arcuri, & Rubichi, 2011). Of particular relevance to the present work, a recent study found that participants primed with interdependent, relational pronouns (e.g., "we" or "us") showed a larger joint Simon compared to participants primed with pronouns referring to the self ("I" or "my"; Colzato, de Bruijn, & Hommel, 2012).

The Development of Joint Action

Previous research has shown that children as young as four years of age show a robust spatial compatibility effect on the standard Simon task (Davidson, Amso, Anderson, & Diamond, 2006; Martin-Rhee & Bialystok, 2008), although to our knowledge there is no published work on the joint Simon task with children. A large body of work on the development of joint action suggests preschool children are able to work with others on multifaceted tasks involving complementary roles (Ashley & Tomasello, 1998; Cooper, 1980; Meyer, Bekkering, Paulus, & Hunnius, 2010).

The precise mechanisms underlying joint action behaviors in young children are not well established, but several proposals suggest co-representation of self and other's actions as one potential mechanism (Barresi & Moore, 1996; Meyer et al., 2010; Tomasello, Carpenter, Call, Behne, & Moll, 2005), which is thought the be a key aspect of action coordination in adults (Sebanz et al., 2006a). Assessing the joint Simon effect in young children could be a useful way of empirically testing these proposals. If there is a joint Simon effect in children, a further question concerns whether the magnitude of this effect is sensitive to social influences as it is in adults (Colzato et al., 2012; Hommel et al., 2009; Iani et al., 2011). In addition to potentially clarifying the mechanisms underlying children's joint action behaviors, addressing these questions will add to our understanding of how children's executive function differs in social and non-social contexts, which as mentioned above has been relatively understudied.

The Influence of Social Interaction on Executive Function

A relatively new line of research in adults suggests that brief social interaction can facilitate executive function (Ybarra & Winkielman, 2012). In one study, participants who took part in a group discussion for 10 minutes before completing a working memory task outperformed control participants who first watched a 10-minute video clip from the television show *Seinfeld* (Ybarra et al., 2008). According to the authors, the social interaction enhanced task performance because it "exercised" (i.e., primed) executive functions therefore increasing their accessibility to be used in the subsequent task. This interpretation is based on the idea that most social interactions involve processes that rely on executive functions (Decety, Jackson, Sommerville, Chaminade, & Meltzoff, 2004). Some of these processes include turn taking, attention, perspective taking, and building a model of the other person (Ybarra et al., 2008).

According to the proposal that social interaction boosts executive functions by increasing their accessibility, situations that discourage participants from engaging in the cognitive processes that require executive function (e.g., perspective taking), would not be expected to have a facilitative effect. Ybarra, Winkielman, Yeh, Burnstein, & Kavanagh (2011) tested this hypothesis in a series of studies in which they manipulated the extent to which the preceding social interaction encouraged participants to create a mental model of the other person, engage with them, and take their perspective. In the first study, participants completed an executive function task (a trail making test) after interacting with a stranger who they were told would be their partner (to encourage engagement) or their opponent (to discourage engagement) in the next phase of the experiment. In line with the hypothesis that mentally engaging with another person is imperative for a social interaction to have a facilitative effect on executive function, participants who interacted with someone who they believed would be their partner, but not participants who interacted with a potential opponent, performed better than a control group who received no social interaction. In a second study, the lack of cognitive benefits for the competitive context was ameliorated if participants played a game that required mind reading and perspective taking (Ybarra et al., 2011).

Although these findings suggest social interaction can have a positive influence on executive function, it is known from other work that high-maintenance social interactions can have a debilitative effect. In one study on this topic, participants were required to navigate through a virtual maze which was invisible to them, but not to an experimenter who provided step-by-step directions to reach the end. Compared to participants who received efficient directions, performance on a subsequent Stroop task was lower for participants whose director consistently changed their mind (Finkel et al., 2006). Another line of research has shown that forced interracial interactions negatively affect executive function performance, particularly for participants with more prejudiced views (Richeson & Shelton, 2003; Richeson & Trawalter, 2005). These types of interactions are thought to deplete executive function resources causing impaired performance on subsequent executive function tasks (Finkel et al., 2006; Richeson & Shelton, 2003). This interpretation is based on the conceptualization of executive function as a limited resource such that engaging in one task that requires self-regulation impairs performance on a subsequent task that requires a similar resource (Baumeister, Bratslavsky, Muraven, & Tice, 1998; Baumeister, Muraven, & Tice, 2000; Muraven, Tice, & Baumeister, 1998).

The Present Study

The studies described above demonstrate that social priming and social interaction can have a substantial influence on executive function processes in adults. The aim of the present study is to examine how a collaborative social interaction influences these processes in early childhood – a period characterized by substantial changes in cognitive control. Social interaction was manipulated for two groups of children (mean age = 59.3 months) and the performance of these groups on various executive function tasks was compared. For one group of children, the social interaction involved completing a goal-directed task in collaboration with an adult experimenter (the "collaborative" condition). Children in another group completed a similar task individually (the "individual" condition). As described above, many studies with adults have used verbal priming tasks to evoke an affiliative frame of mind in their participants. In the current study, collaboration was used as a developmentally appropriate substitution for priming interdependence. Following the manipulation phase, children completed a motor contagion task, a standard Simon task, an individual go/no-go task, and two joint go/no-go tasks.

The study was designed to address four specific questions. First, we examined if priming interdependence through collaboration influences children's performance on a subsequent motor contagion task. Second, we explored whether children show the joint Simon effect when sharing a Simon task with another person. A related third question was if children do show the joint Simon effect, can it be modulated by the nature of a preceding social interaction. Lastly, motivated by the work of Ybarra and colleagues (2008; 2011) we sought to examine whether engaging in collaboration, a form of social interaction, influenced children's general response inhibition compared to working alone. Collaboration versus working individually is thought to require inhibitory control since one must override self-serving behaviors in order to coordinate one's own actions with the actions of the other person in order to reach the shared goal (Adolphs, 2003).

Consistent with this, developmental studies have indicated a strong correlation between inhibitory control and cooperative behavior (Ciairano, Visu-Petra, & Settanni, 2007; Giannotta, Burk, & Ciairano, 2011). The specific predictions for each of the four questions are described below.

Question 1: How Does Engaging in a Collaborative Social Interaction Influence Motor Contagion in Preschool Children?

Based on the findings reviewed above that priming interdependence versus independence increases automatic imitation of observed movements in adults (Leighton et al., 2010; van Baaren et al., 2003), children in the collaborative condition were expected to show greater interference on the motor contagion task compared to children in the individual condition. A supplementary question was whether children in the collaborative condition would show differences related to whether the actor producing the observed movements was the person they had collaborated with in the manipulation versus someone else. With the exception of a recent study with adults (Kourtis, Knoblich, & Sebanz, 2013), existing work relevant to this question is extremely limited.

Question 2: Do Young Children Show the Joint Simon Effect When Sharing an Executive Function Task with an Adult?

In line with the work on the joint Simon effect in adults, we expected to find a spatial compatibility effect when children completed the joint go/no-go task with the experimenter, but not when they completed the go/no-go task individually.

Question 3: How Does Engaging in a Collaborative Social Interaction Influence the Joint Simon Effect in Preschool Children?

In line with the existing work with adults which suggests a more interdependent mindset is associated with a larger joint Simon effect (Colzato et al., 2012; Iani et al., 2011), children in the collaborative condition were expected to show a larger joint Simon effect compared to children in the individual condition. We were also interested in whether there would be differences in the extent of the joint Simon effect for children in the collaborative condition when they completed the joint Simon task with their previous collaboration partner versus a different experimenter.

Question 4: How Does a Prior Social Interaction Influence Children's General Response Inhibition?

Relatively new research with adults has provided preliminary evidence that social interaction facilitates subsequent executive function possibly through a process of resource priming (Ybarra et al., 2008). Given that collaborating with another person requires inhibitory control, children in the collaborative condition were expected to show better response inhibition compared to children who worked individually. Accuracy on the individual go/no-go task and standard Simon task were used to explore this question. Compared to the motor contagion task and joint go/no-go tasks, these tasks do not involve a social component so they would not be affected by the social manipulation unless the manipulation had a more general influence on executive function.

CHAPTER 2

METHODS

Participants

Sixty-four 4-and 5-year-old children participated in the study (*M* = 59.3 months, *SD* = 4.7 months; 33 male). Children were recruited from eight childcare centers and schools in the greater Philadelphia area. Center directors or principals were sent a letter describing the details of the study. For preschools whose directors agreed to participate, a consent form and flyer describing the study was sent home with children in the pre-kindergarten class or classes. Children whose parents returned the signed consent form to the preschool were the participants in the study. Parents were also asked to report basic demographic information about their child. Based on these responses, 76% of the children were Caucasian, 6% African-American, 2% Hispanic, 2% Asian, and 14% other or mixed ethnicities.

Procedure

Data collection involved three experimenters visiting each preschool facility. Individual children were randomly assigned to either a "collaborative" or "individual" condition. An experimenter (Experimenter 1) went to the children's classroom and invited them one-by-one to accompany her to a quiet area of the preschool to play a series of games. She further explained that they would receive a sticker after each game, and when they collected six stickers they would get a certificate to take home.

Social Manipulation

In the first phase of the experiment, Experimenter 1 introduced the child to two additional experimenters (Experimenters 2 and 3) and then explained the first “game”. Children either completed this task individually (the individual condition) or in collaboration with one of the two new experimenters (the collaborative condition). The game was a modified version of a task that has been used in a previous study of collaboration in young children (Warneken, Chen, & Tomasello, 2006). The experimental apparatus involved a single tube (referred to as a “telescope”) mounted on a tripod base that was stabilized by weights. The tube could pivot like a seesaw, but was pulled down on one end by a spring such that it naturally returned to one orientation (see Figure 1).

The task objective was to use the device to move a set of 18 green ping-pong balls from one bucket to another. To successfully move a single ball, children had to choose one from a starting bucket, lift the spring-loaded end of the tube with one hand, and place the ball inside so that it would roll down and fall into the other bucket. For children in the collaborative condition, a cap was placed on the far end of the tube such that the task could only be completed with two people - another person had to retrieve the ball from a window on the surface of the tube, while another person continued to hold up the other (spring-loaded) end. In this condition, an experimenter (Experimenter 2; the “partner”) participated in the activity with the child. After being told the goal of the task, Experimenters 1 and 2 modeled the task for the child with Experimenter 1 placing a single ball in the top of the tube and Experimenter 2 taking it out of the window and placing it in the bucket. To insure that the children understood that the task could not be completed alone, they were also shown a demonstration in which Experimenter 2 did not retrieve the ball from the window and it rolled back to the open end when the tube was released by Experimenter 1. After seeing a successful and unsuccessful example, children were given a chance to try taking the place of Experimenter 1 by placing a ball in the tube and tilting it such that Experimenter 2 could retrieve it. Once they had completed this successfully for one ball, Experimenter 1 told the child that she was "going to go set up the other games" and that the child should finish moving all the balls by working together with Experimenter 2. When the child and Experimenter 2 had moved 9 out of the 18 balls to the bucket, Experimenter 2 asked the child to switch roles so that the child now retrieved the balls from the window of the tube and placed them in the bucket. The third experimenter (Experimenter 3; the "observer") who was in the room when the child entered, was also present throughout the task, but did not contribute to the collaboration. At the start of the task, Experimenter 3 told the child that she was going to sit near them and read a magazine.

For children in the individual condition, there was no cap on the far end of the tube such that the ball rolled straight into the bucket and therefore no partner was required. As with the collaborative condition, Experimenter 1 modeled the task for the child and then asked the child to try it. Once the child successfully got one ball into the bucket, Experimenter 1 left the room. Children were instructed to try and get all the balls in the bucket, but were told that it was okay if they missed some. The children missed approximately 3 balls on average. Experimenters 2 and 3 were present while the child completed the task, but for this condition both experimenters played the role of observers.

In both conditions, Experimenters 2 and 3 made statements during the task that subtly highlighted its joint or individual nature. Both experimenters' comments were based on scripts to ensure consistency across participants (Appendix A).

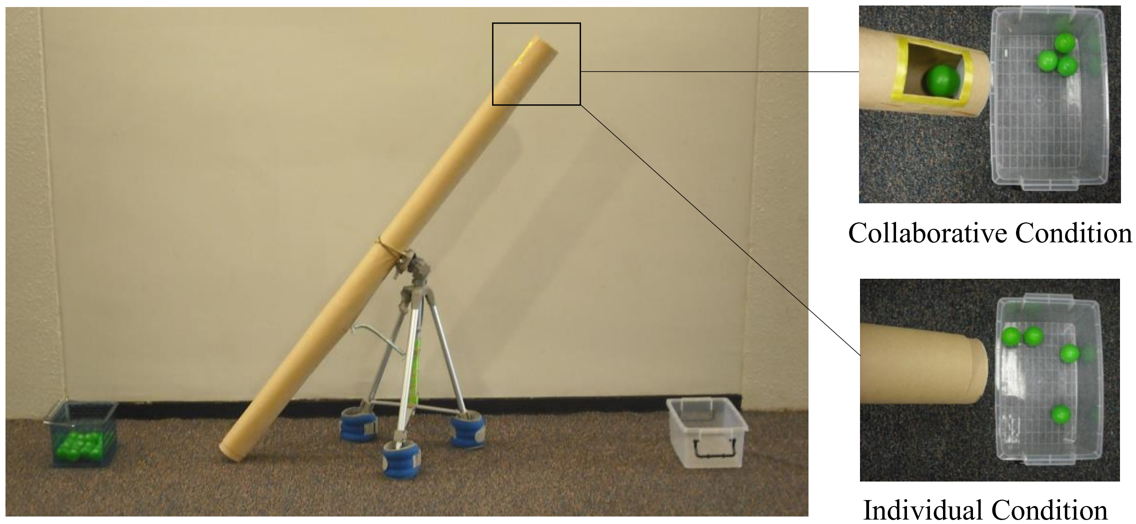

Figure 1. The apparatus used in the manipulation. Children had to move the ping-pong balls from one bucket to the other using the "telescope" device. For children in the collaborative condition, the end of the tube was closed so another person had to retrieve the ball from the window on the surface. For children in the individual condition, the end of the tube was open so the ball rolled straight into the bucket.

Following the social manipulation, children completed a battery of four tasks administered by Experimenter 1. The order of tasks was fixed across participants: The motor contagion task, the individual go/no-go task, the Simon task, and the joint go/no-go (joint Simon) task. Children in the collaborative condition were first asked to identify which of the two experimenters they worked with during the game. Experimenter 1 showed them two pictures, one of each of the experimenters from the manipulation, and asked the child, "Can you show me who helped you?" Eighty-seven percent of children chose correctly.

Motor Contagion Task

Materials

Four silent video clips were created for the motor contagion task, each showing Experimenter 2 or 3 from the previous manipulation making sinusoidal movements with her right arm (each clip = 15 s) in the horizontal or vertical axis. An LCD graphics tablet (Wacom PL-550; 30 x 23 cm viewable) was used to simultaneously display the background video stimuli and to record participants' movements (as in Marshall et al., 2010 and Saby et al., 2011; see Figure 2). A cardboard frame was placed on the tablet to restrict the visible area to a square (19 x 19 cm, 485 x 485 pixels).

Figure 2. Photograph of the LCD graphics tablet showing a background video clip.

Procedure

Participants were seated on a booster seat in order to give them an optimal view of the video stimuli. Each child was told that they would be moving a "pen" (i.e., the tablet stylus) on the screen and that while they might see different movements on the screen, they should always move the pen "up and down". Experimenter 1 demonstrated the up and down movement, drawing on the tablet while the display remained blank. The child was then given the stylus to practice moving up and down on the tablet. Once the child appeared to understand the motion required, he or she completed eight experimental trials in which the stylus was moved up and down while one of the four videos was displayed in the background (2 trials of each). Children also completed two 15 s trials without anything being displayed on the tablet ("blank screen" trials). Prior to each trial, the experimenter reminded the child to move the pen up and down.

Children were randomly assigned to one of fourteen trial orders (Appendix B). To maintain the child's interest, there was a brief break (5 s) after each trial during which the child saw an animation (e.g., ocean waves) and heard a background melody. The *x* and *y* coordinates of the stylus position on the tablet were recorded using Macro Recorder (Jitbit Software, London, UK) with the stylus leaving no trace on the tablet screen. Figure 3 shows an example of one child's stylus movements.

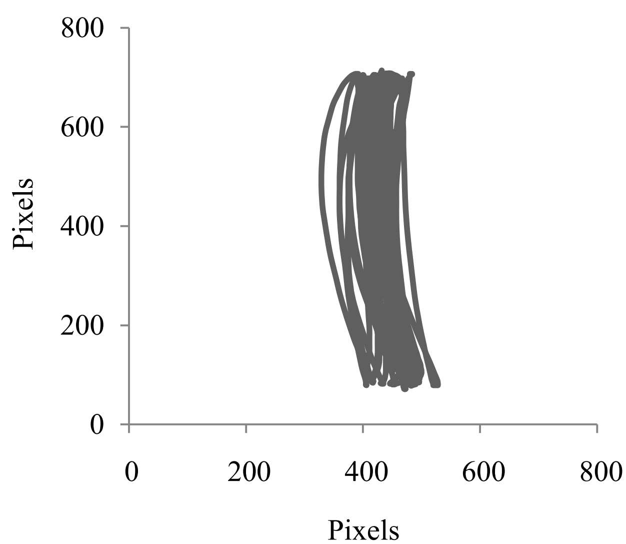

Figure 3. <u>An example data series of stylus coordinates from one child's movements in a single trial in the motor contagion task.</u>

Methods Common to the Standard Simon and Go/No-Go Tasks

After the motor contagion task, children completed an individual go/no-go task, a Simon task, and a go/no-go task jointly with each experimenter from the social manipulation. All tasks were presented on a laptop (screen size 32 x 19 cm) using E-Prime (Psychology Software Tools, Pittsburgh, PA) to present and record responses. Responses were made on two button boxes (6.5 x 11.5 x 2.5 cm; James Long Company, Caroga Lake, NY) with a single pushbutton (7.5 mm diameter).

Experimenter 1 first showed the child laminated pictures of a frog and a butterfly and asked the child to name them. Before each task, the experimenter gave the child instructions regarding what they should do when they see the frog or butterfly appear on the screen. The order of the tasks was fixed with the go/no-go task first, followed by the standard Simon task, and lastly the joint go/no-go (joint Simon) tasks (see Table 1). The reason for this order is that the joint go/no-go task may be perceived as a type of collaboration. Therefore, this task was carried out at the end in order to maintain the distinction between the collaborative and individual conditions.

For all four tasks, the inter-trial interval was 1.5 seconds and each stimulus was displayed until the child responded, or until 2 s had elapsed. These parameters were based with previous work using a Simon task with children of this age (Davidson et al., 2006; Simpson & Riggs, 2006). For each task, children completed four practice trials prior to the experimental trials. During the practice period, the children received feedback from the experimenter on whether or not their response was correct. Children were required to respond correctly on three out of the four practice trials (75%) to move on to the experimental trials. For the individual go/no-go and standard Simon tasks, this criterion was reached by 80% of the children in one practice set. For the joint go/no-go tasks, 100% of children met the criterion on the first attempt.

Following the practice trials, children completed 20 experimental trials. Children were instructed to respond as quickly as possible without making mistakes, and reaction time and accuracy data were recorded using E-Prime. Small pictures of the stimuli were placed on the appropriate button box to help children remember which stimulus was associated with which button (as in Davidson et al., 2006).

Methods Specific to the Individual Go/No-Go Task

Participants were seated with their face 25 cm in front of and 25 cm to the right of the midline of the laptop screen. Using the laminated cards as a visual aid, the experimenter explained to the child that they will see the frog and butterfly appear on the screen and that they were supposed to “catch” the frogs by pressing the button. They were further told not to press the button when they see butterflies because they needed to “let them go”. These instructions were counterbalanced such that half the children were instructed to “catch” the butterflies, but not the frogs. During the test session, the butterfly and frog were presented in a random order on the right or left side of the screen for 20 trials (10 go trials, 10 no-go trials).

Methods Specific to the Standard Simon Task

For the standard Simon task, the child was given a second button and was seated centrally in front of the laptop screen. The two button boxes were placed 30 cm apart (the length of the laptop keypad) in front of the child. The experimenter explained to the child that they should now respond to both types of pictures. The specific instructions were, “Now instead of letting the butterflies go, you are going to catch them too. If you see a frog, catch it by pressing this button (pointing to left/right button). If you see a butterfly, catch it by pressing this button (pointing to the right/left button).” For the experimental trials, the frog and butterfly were presented randomly on the left and right of the screen over 20 trials (10 spatially compatible and 10 spatially incompatible).

Methods Specific to the Joint Go/No-Go Task

For the final task, children carried out two rounds of a joint go/no-go task, once with each of the experimenters present during the social manipulation. Children were again seated on the right side of the laptop 25 cm in front of the screen and 25 cm from the midline. One of the experimenters (Experimenter 2 or 3) was seated 50 cm to their left (25 cm from the midline of the laptop). Children received instructions from Experimenter 1 that they should respond to one of the two stimuli and that the other person will respond to the other animal. The stimulus to which the children were assigned for both joint tasks was the same as in the go/no-go tasks. The exact instructions were, “For this game, instead of you catching the butterflies, now (Yana) is going to catch them. So when you see a frog, press your button, and (Yana), when you see a butterfly, press your button.” As for the individual go/no-go task, the instructions were counterbalanced such that half the children were instructed to catch the butterflies instead of the frogs. When the first joint go/no-go task was completed, the other experimenter from the manipulation took the current experimenter’s place and the task was repeated. Instructions were given prior to both joint tasks.

Peabody Picture Vocabulary Test

At the end of the session, children's receptive vocabulary was assessed using the *Peabody Picture Vocabulary Test III* (PPVT-III; Dunn & Dunn, 1997). Children were shown plates of four pictures and asked to point to the picture that best represents the meaning of a word presented orally. The PPVT was included to rule out the possibility that any differences found between conditions on the experimental tasks were due to differences in children's vocabulary level.

Data Analysis

Motor Contagion Task

Standard deviation in stylus position in the axis the child was not instructed to move in (i.e., the horizontal axis) was calculated for each trial. In the presentation of results this axis will be referred to as the "error axis" (Marshall et al., 2010). Since children completed two trials of each type, the SD values from both trials were averaged and used in the analysis. The focus on variability in the axis orthogonal to the axis the child was instructed to move in is consistent with other studies of motor contagion (Bouquet et al., 2007; Kilner et al., 2007; Stanley, Gowen, & Miall, 2007).

Standard Simon and Go/No-Go Tasks

Response times shorter than 200 ms were considered as artifactual and were excluded from the analyses. Task performance was assessed based on accuracy (i.e., percentage of correct responses) and reaction time. The percentage of correct responses was calculated as the number of correct responses divided by the total of correct and incorrect responses.

For the individual and joint go/no-go tasks, responses were considered correct if 1) the child pressed their button on a "go" trial (i.e., when the stimulus they were instructed to respond to is presented on the screen) during the allotted response period of 2 s or 2) did not press the button on a "no-go" trial (i.e., when the stimulus they were instructed not to respond to is presented on the screen). Mean reaction time was derived from responses on correct go trials.

For the standard Simon task, no response within the allotted 2 s period was also considered incorrect. In addition, pressing the wrong response button for a given stimulus (i.e., the button that corresponds to the other animal) was counted as an incorrect response.

In addition to task performance, spatial compatibility effects were analyzed for each task. Reaction times three standard deviations away from a participant's mean were removed prior to this analysis. Across tasks, 7% of all responses were removed through this process. Spatial compatibility effects were assessed by directly comparing reaction times on compatible and incompatible trials. When comparing the collaborative and individual conditions, the difference in reaction time on incompatible and compatible trials (reaction time on incompatible trials minus reaction time on compatible trials) was used to index the extent of spatial compatibility effects.

CHAPTER 3

RESULTS

Motor Contagion Task

Fifty-three of the 64 participating children were included in the analyses of the motor contagion task. The other 11 children were excluded due to technical problems (n = 6) or because they did not have enough useable data for at least one of each trial type (e.g., drew circles for part of trial; n = 5). Of the 53 remaining children, a further 11 children were excluded from analysis of the motor contagion data due to extreme values of stylus coordinates (more than 1.5 times the interquartile range from the group median) on one or more trials. Of the 42 children in the final analysis, 21 were in the collaborative condition and 21 were in the individual condition.

An initial paired *t*-test was carried out to compare the effect of congruency on variability in stylus position for all participants, regardless of group. Consistent with previous work using this task (Marshall et al., 2010; Saby et al., 2011), the standard deviation of stylus position in the error axis was greater for trials in which children observed incongruent (i.e., horizontal) movements compared to congruent (i.e., vertical) movements ($t(41) = 2.17$, $p = .036$; see Figure 4). In addition, the standard deviation of stylus coordinates in the error axis was significantly smaller for the congruent trials compared to the trials when children moved the pen in the absence of a background display ($t(41) = 3.06$, $p = .004$).

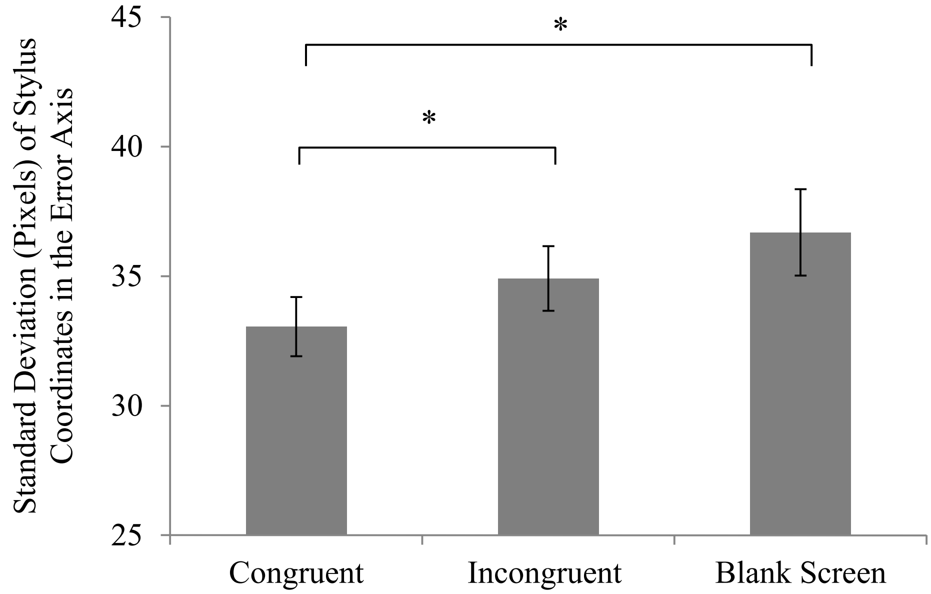

Figure 4. Mean standard deviation (in pixels) of stylus coordinates in the error axis across experimental conditions. Error bars represent ±1 SEM, and significant differences are indicated (* p <.05).

To examine if there were differences in motor contagion between the two conditions, standard deviation in the error axis was entered into a repeated measures analysis of variance (ANOVA) with congruency (congruent vs. incongruent) as a within-subjects factor and condition (collaborative vs. individual) as a between-subjects factor. There was a main effect of congruency ($F(1, 40)= 4.59$, $p = .038$), but no significant main effect of condition ($F(1, 40)= .011$, $p = .916$) or significant interaction between congruency and condition ($F(1, 40)= .061$, $p = .806$).

Effect of Partner versus Observer on Motor Contagion

For children in the collaborative group, further analyses were performed to examine if there were differences in motor contagion related to children's prior experience with the model in the video display. To address this question, a repeated measures ANOVA was carried out with factors of congruency (congruent vs.

incongruent) and model (partner vs. observer). There were no main effects of congruency (F(1, 40)= 1.88, p = .186) or actor (F(1, 40)= 1.033, p = .322), but there was a significant interaction between these factors (F(1, 20) = 4.75, p = .042). Post-hoc t-tests showed the interaction was due to significantly greater variability in the error axis when observing incongruent movements made by the experimenter who the child collaborated with compared to observing incongruent movements made by the experimenter who simply observed the collaboration (t(20)= 2.11, p = .047). Furthermore, for trials in which children observed movements of their former collaborative partner, there was significantly greater standard deviation in the error axis for incongruent compared to congruent trials (t(20) = 2.24, p = .037). The difference between incongruent and congruent trials was not significant for trials in which the observer was on the screen (t(20) = .514, p = .613).

As mentioned in the methods, children were asked to identify their partner from the collaboration immediately following the original social manipulation, with 87% of children providing the correct answer. When children who incorrectly identified their partner were removed from the analysis of children in the collaborative condition, the interaction between congruency and actor appeared to become stronger (n = 2; F(1, 18) = 8.99, p = .008). Again, this interaction was due to greater variability in the error axis when observing incongruent movements produced by the partner compared to the observer (t(18)= 2.12, p = .048; see Figure 5).There was also a significant difference between congruent and incongruent trials for trials in which children saw their partner

($t(18) = 2.28$, $p = .035$), but not for incongruent and congruent trials in which the children saw the observer ($t(18) = 1.43$, $p = .170$).

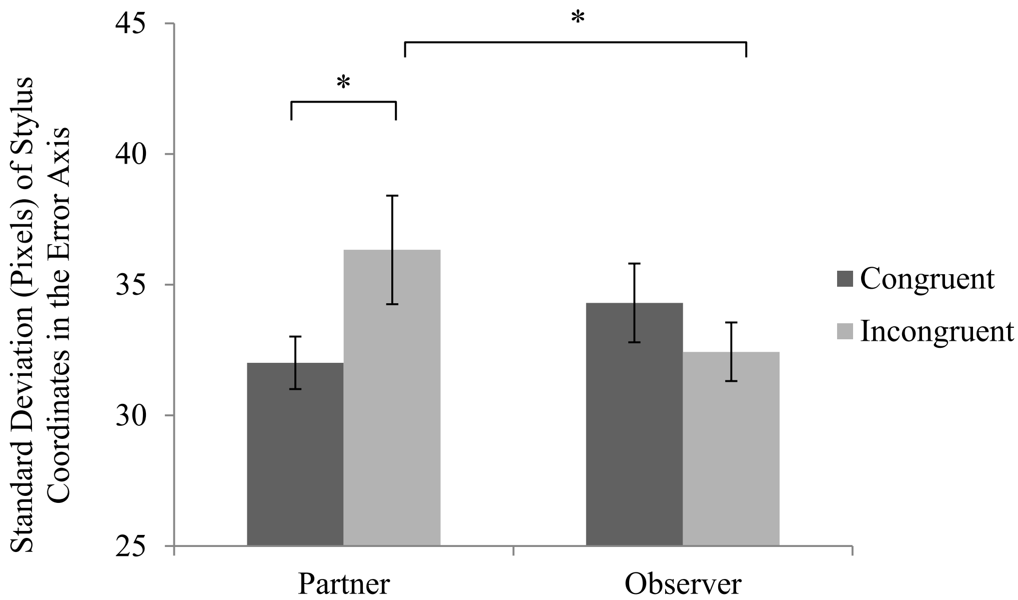

Figure 5. Mean standard deviation (in pixels) of stylus coordinates in the error axis for children in the collaborative condition who correctly identified their partner ($n = 19$). Greater motor contagion was induced from observing incongruent movements of the partner compared to the observer. Error bars represent ±1 SEM, and significant differences between conditions are indicated (* $p < .05$).

Individual Go/No-Go Task

Task Performance

Sixty-two children were included in the analyses of the go/no-go and Simon tasks. The remaining two children were excluded from the analyses of these tasks due to failure to comply with task instructions. Overall, children attained a high level of accuracy on the individual go/no-go task (M= 96.7% correct, SD= 5.1). There were no significant differences between the collaborative and individual conditions in accuracy ($t(60) = .362$, $p = .719$) or reaction time ($t(60) = 1.28$, $p = .207$). Means are displayed in Table 1.

Spatial Compatibility

Spatial compatibility effects were assessed by comparing reaction times on compatible and incompatible trials using paired *t*-tests. This analysis revealed no difference in reaction time between compatible (M = 774.0 ms, SD = 212.8) and incompatible trials (M = 786.3 ms, SD = 189.9; $t(61)$ = .831 p = .409; see Figure 6). In addition, the difference between reaction time on incompatible and compatible trials did not differ between collaborative and individual conditions ($t(60)$ = 1.49, p = .142).

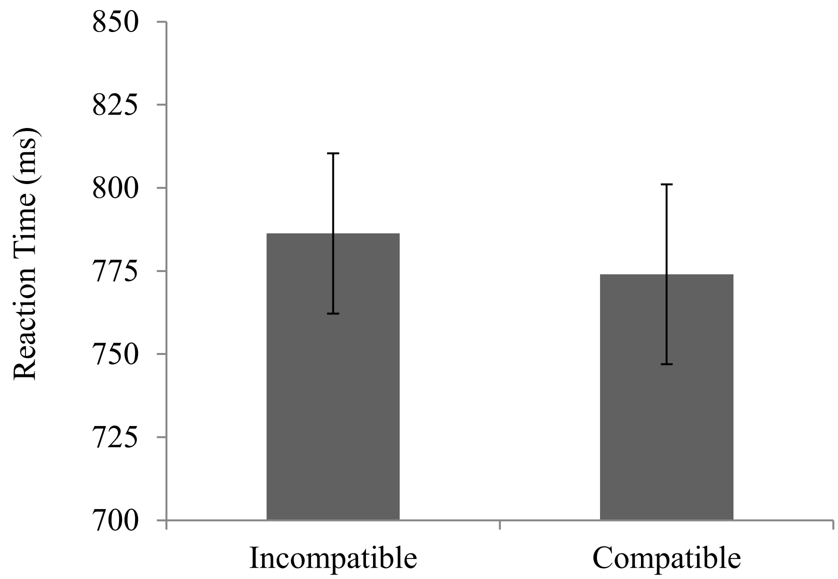

Figure 6. Reaction times for the individual go/no-go task. Overall mean reaction time for incompatible and compatible trials. Error bars represent ±1 SEM. The difference in means is not statistically significant.

Standard Simon Task

Task Performance

Mean accuracy on the standard Simon Task was high (M = 91.3%, SD= 9.1), which is consistent with other investigations of the Simon task in young children

(Davidson et al., 2006). Neither accuracy nor reaction time differed between the collaborative and individual conditions ($t(60) = .485$, $p = .629$; $t(60) = 1.40$, $p = .167$, respectively).

Spatial Compatibility

As predicted, mean reaction time was faster on compatible compared to incompatible trials, (869.4 vs. 993.8 ms; $t(61) = 8.97$, $p < .001$; see Figure 7). The difference in reaction time on incompatible and compatible trials (i.e., the spatial compatibility effect) did not differ between the collaborative and individual conditions ($t(60) = .223$, $p = .824$).

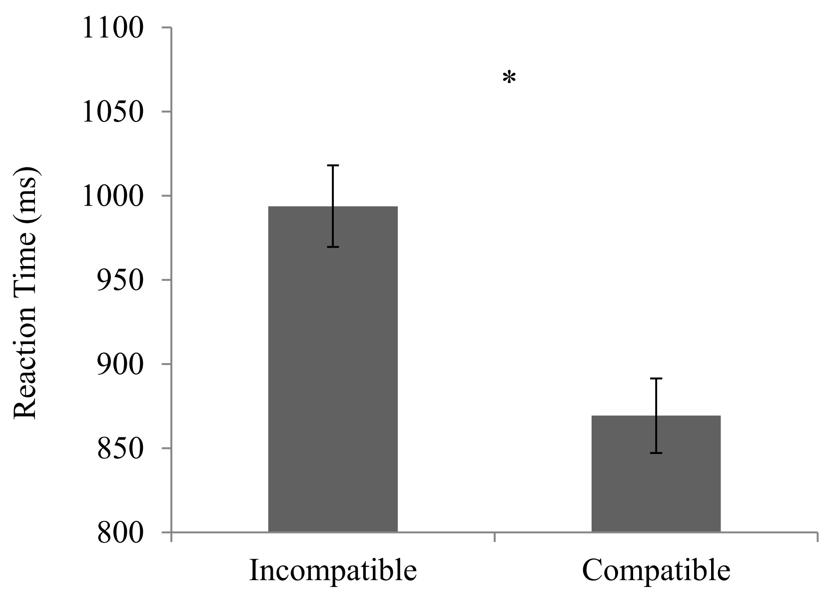

Figure 7. Reaction times for the standard Simon task. Overall mean reaction time for incompatible and compatible trials. Error bars represent ±1 SEM, and significant differences between conditions are indicated (* p <.05).

Joint Go/No-Go (Joint Simon) Tasks

Task Performance

Across both conditions, children achieved a high level of accuracy on the first (*M*= 98.8% correct, *SD*= 2.4) and second (*M*= 98.6% correct, *SD*= 2.9) joint go/no-go task. Accuracy did not differ for the collaborative and individual conditions on the first ($t(60) = 1.15$, $p = .255$) or second joint go/no-go task ($t(60) = .099$, $p = .922$). Reaction times were also comparable across the conditions on the first ($t(60) = .856$, $p = .396$) and second ($t(60) = 1.16$, $p = .252$) joint task.

Spatial Compatibility

When reaction times for the first and second joint go/no-go tasks were averaged, the difference between spatially compatible (*M* = 677.3 ms, *SD* = 128.6 ms) and spatially incompatible trials was not significant (*M* = 692.1 ms, *SD* = 117.3 ms; $t(61) = 1.65$, $p = .104$). Further analyses examined the first and second joint go/no-go tasks separately. The first time children completed the joint go/no-go task, responses on spatially compatible trials (*M* = 685.5 ms, *SD* = 131.4) were significantly faster than responses on spatially incompatible trials (*M* = 708.8 ms, *SD* = 141.0; $t(61) = 2.15$, $p = .035$; see Figure 8). The extent of this spatial compatibility effect did not differ between the collaborative (*M* = 22.2 ms, *SD* = 88.1) and individual (*M* = 24.2 ms, *SD* = 83.6) conditions ($t(60) = .092$, $p = .927$).

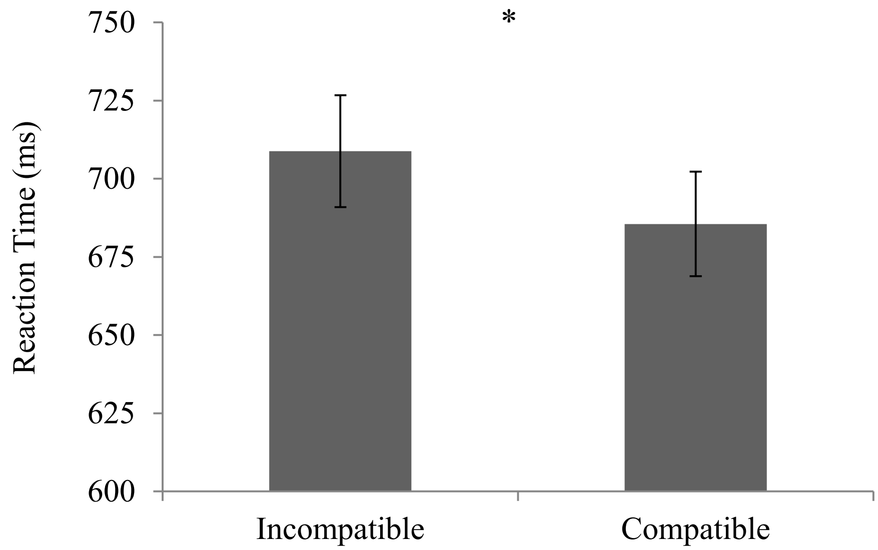

Figure 8. Reaction times for the first joint go/no-go task. Mean reaction times for incompatible and compatible trials from the first time children completed the joint go/no-go task. Error bars represent ±1 SEM, and significant differences between conditions are indicated (* p <.05).

The second time children completed the joint task, there was no difference in reaction time between compatible (*M* = 669.1 ms, *SD* = 152.1) and incompatible trials (*M* = 675.4 ms, *SD* = 124.5; $t(61) = .434$, $p = .666$; see Figure 9). Additional analyses showed the difference in incompatible and compatible trials did not differ between the collaborative (*M* = -.05 ms, *SD* = 116.3) and individual conditions (*M* = 12.2 ms, *SD* = 113.3; $t(60) = .421$, $p = .675$).

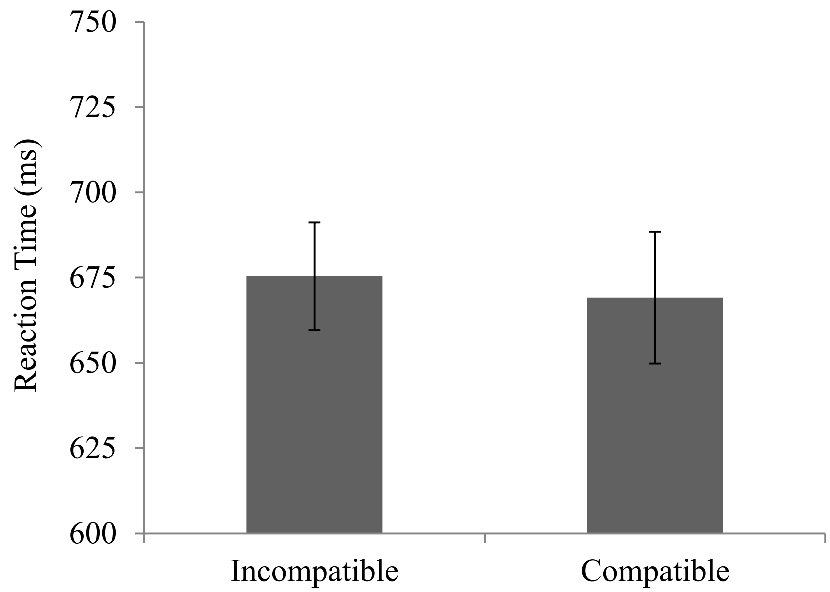

Figure 9. Reaction times for the second joint go/no-go task. Mean reaction times on incompatible and compatible trials in the second joint go/no-go task. Error bars represent ±1 SEM. The difference is not significant.

Effect of Partner versus Observer on Spatial Compatibility

For children in the collaborative condition, analyses were conducted to examine if there were differences in the spatial compatibility effect on the joint go/no-go task when the co-actor was the child's partner from the collaborative activity versus the observer. To address this question, the difference in reaction time on incompatible and compatible trials when completing the go/no-go task with the partner was compared with the difference in reaction time on incompatible and compatible trials when completing the task with the observer. This analysis revealed that the spatial compatibility effect associated with sharing a task with the partner (M = -7.44 ms, SD = 80.4) was not significantly different from the effect associated with acting with the observer (M = 29.6 ms, SD = 119.8; $t(47.81) = 1.41$, p = .169).

Table 1
Accuracy and Reaction Time for Go/No-Go and Simon Tasks by Condition (with Standard Deviations in Parentheses)

	Condition		
Accuracy (percentage of correct responses)	Collaborative	Individual	Overall
Individual go/no-go	97.0 (4.5)	96.5 (5.7)	96.7
Standard Simon task	91.8 (8.9)	90.7 (9.3)	91.3
First joint go/no-go	98.5 (3.0)	99.2 (1.8)	98.8
Second joint go/no-go	98.7 (2.6)	98.6 (3.2)	98.6
Reaction Time (ms)			
Individual go/no-go	812.3 (205.7)	750.0 (178.6)	781.2
Standard Simon task	963.3 (173.3)	901.9 (172.9)	932.6
First joint go/no-go	711.7 (135.9)	683.5 (123.8)	697.6
Second joint go/no-go	691.4 (133.6)	654.3 (119.4)	672.9

PPVT-III

The mean PPVT-III score for the entire sample was 106.1 (SD = 16.1). Despite random assignment on a child level within each preschool, children in the individual condition had overall higher PPVT scores compared to children in the collaborative condition (M = 110.5, SD = 15.1 and M = 101.6, SD = 16.1, respectively; $t(61)= 2.28$, p = .026). To test if differences in PPVT may have contributed to differences in task performance between the two conditions, bivariate correlations were used to examine whether PPVT scores were correlated with the dependent variables on each task.

For the motor contagion task, PPVT scores were not significantly correlated with the standard deviation of stylus movements in the error axis on congruent ($r(42)$ = .099, p = .534), incongruent ($r(42)$ = .051, p = .748), or blank screen trials ($r(42)$ = -.062, p = .698). In addition, PPVT scores were not significantly correlated with accuracy on the individual go/no-go task ($r(62)$ = -.085, p = .509), the Simon task ($r(62)$ =

.049, p = .707), or the first or second joint go/no-go tasks (r(62) = -.008, p = .952; r(62) = .062, p = .633, respectively). PPVT scores were not significantly correlated with the difference in reaction time on incompatible and compatible trials (i.e., the spatial compatibility effects) for any task except the second joint go/no-go task for which there was a weak positive relation, r(62) = .258, p = .043.

CHAPTER 4

DISCUSSION

There is currently great interest among developmental scientists in executive function in preschool children. However, the existing research in this area has focused on children at the individual level which overlooks the social nature of children’s everyday lives. The current study attempted to fill this gap by addressing four specific questions concerning social influences on executive function performance in preschool children. The first question was whether children who had just collaborated with an experimenter showed differential performance on a motor contagion task compared to children who had worked alone. The second and third questions concerned the joint Simon effect, namely if the joint Simon effect is elicited when preschool children share a Simon with another person and if the extent of the effect can be modulated by aspects of a preceding social interaction. Lastly, we explored whether engaging in collaboration had any general effects on children’s ability to inhibit prepotent responses.

The main finding from the motor contagion task was that children in the collaborative group were more susceptible to interference from incongruent movements when they were produced by their collaborative partner compared to the person who observed the collaboration. The other main result from the study was the presence of a joint Simon effect the first time children completed a task with an experimenter, although the extent of the effect was not affected by the preceding social manipulation. In addition, the manipulation did not affect children’s overall response inhibition indexed by accuracy on the individual go/no-go and Simon task. The implications of the findings for each of the four questions are discussed here.

Influence of Collaboration on Motor Contagion

Previous work has demonstrated that adults show increased imitation in more naturalistic settings and on automatic imitation tasks following verbal tasks aimed to enhance an interdependent versus independent frame of mind (Cook & Bird, 2011; Leighton et al., 2010; Spengler et al., 2010; van Baaren et al., 2003). To examine whether priming these different frames of mind influences similar processes in children, participants completed a motor contagion task following the social manipulation in which they acted individually or in collaboration with an experimenter.

Initial analyses of the data from the motor contagion task demonstrated that there was a significant motor contagion effect across groups. Specifically, the variability of children’s movements in the error axis was greater when observing incongruent versus congruent movements. This finding is consistent with prior work using this task (Marshall et al., 2010) and related studies in adults (Bouquet et al., 2007; Kilner et al., 2007; Kilner et al., 2003).

Concerning the question of social influences on motor contagion, it was expected that children who just completed a collaborative task would show overall greater motor contagion compared to children who completed the task individually. This specific hypothesis was not supported: There was no difference in the overall magnitude of motor contagion between the two conditions. However, further analyses demonstrated that children in the collaborative condition were more susceptible to motor contagion when observing the movements of the partner compared to the observer. Therefore, collaborating with another person had a significant influence on children's motor contagion, but this effect was specific to their previous collaborative partner.

A priori, we did not have any specific expectations about differences in the extent of motor contagion related to the partner versus the observer since the existing investigations of the effects of social priming on motor contagion in adults have used non-social (i.e., verbal) tasks. However, consistent with our results, a recent electroencephalography (EEG) study with adults found greater mu rhythm desynchronization, an index of sensorimotor activation, in participants when observing actions of a previous joint action partner compared to observing the same actions performed by someone they had not acted with (Kourtis et al., 2013). To our knowledge, no prior developmental work has examined how acting jointly with another person influences cognitive or neural process associated with subsequent observation of that person's actions. However, relevant to the topic of the short-lasting effects of joint action, one study examined how joint music making influences prosocial behaviors in 4-year-old children. Kirschner & Tomasello (2010) found that joint music making increased the extent to which children helped and cooperated with another child that contributed to the music activity. Although not addressed by the authors, it is interesting to speculate whether a similar increase in prosocial behaviors would have been found if children were paired with a child who was not involved in the initial joint activity.

Joint Simon Effect

Another main goal of this study was to assess how young children's executive function differs between joint and individual contexts. When two adults complete complementary components of a Simon task (i.e., a joint Simon task), reaction times on incompatible trials are significantly slowed compared to compatible trials. This spatial compatibility effect is absent when adults complete the same part of the task without a partner (Sebanz et al., 2003; Welsh et al., 2007). The results of the current study are consistent with the adult work. In the current sample of children, there was no difference in reaction time between compatible and incompatible trials on the go/no-go task. However, the first time children completed a go/no-go task alongside an experimenter, responses were significantly slower on incompatible versus compatible trials, indicating the presence of a joint Simon effect. To our knowledge, no published work to date has demonstrated a joint Simon effect in children.

It is notable that the spatial compatibility effect in the joint go/no-go task was substantially smaller than in the standard Simon task when children were responding to both the frog and the butterfly. A similar pattern has been reported by studies with adults including standard and joint Simon tasks (Atmaca, Sebanz, Prinz, & Knoblich, 2008; Welsh et al., 2007). The finding that the joint Simon effect is not as robust as the standard Simon effect has been considered evidence that the conflict that arises at the level of response selection in the joint condition is less pervasive compared to when participants respond to both stimuli (Atmaca et al., 2008).

Although recent work suggests the joint Simon effect may be partly accounted for by perceptual processes (Dolk et al., 2013), the spatial compatibility effect that emerges in the joint condition is also thought to reflect the participant representing the actions of their co-actor as if they were their own (Sebanz et al., 2003; Welsh et al., 2007). While there is a great deal of evidence that preschool children are able to perform joint activities directed towards a shared goal, little is known about the mechanisms underlying this ability (Brownell, 2011). Several proposals suggest that children's capacity for joint action is aided by the integration of self and other actions into a single, common framework (Barresi & Moore, 1996; Meyer et al., 2010; Tomasello et al., 2005). The current finding of a joint Simon effect in 4.5-year-old children provide support for these proposals, which so far have been offered in the absence of empirical research with children.

The current finding also connects with a literature on children's memories for joint activities. Although preschool children are able to collaborate with others on relatively complex tasks, they commonly make errors when they are subsequently asked to recall details of the event. Specifically, children tend to overestimate their contribution to a collaborative activity and underestimate their partner's contribution (Foley, Passalacqua, & Ratner, 1993; Ford, Lobao, Macaulay, & Herdman, 2011). It has been suggested that this "appropriation bias" emerges because children represent actions of the self and other in a common framework during the collaboration and therefore struggle to differentiate at recall (Foley & Ratner, 1998; Sommerville & Hammond, 2007). The presence of a joint Simon effect in the current study is consistent with this suggestion that children integrate actions of the self and other when completing joint tasks.

Returning to the wider question concerning social influences on executive function, the differential findings from the individual go/no-go task and joint go/no-go task demonstrate that children's executive processes differ when working with another person compared to completing the same task alone. To date, children's executive function has largely been studied in socially isolated contexts, which overlooks the fact that the majority of children's lives involve interacting with others (Lewis & Carpendale, 2009). The current finding suggests the joint Simon task may be a useful tool to study children's executive function in joint contexts, which may provide novel information about children's executive function in more naturalistic situations.

Thus far, this section of the discussion has focused on the finding of a joint Simon effect the first time children completed a go/no-go task with an experimenter. However, on the second joint go/no-go task, there was no difference in reaction time between the compatible and incompatible trials. The absence of a continued joint Simon effect may be a consequence of poor task engagement. Indeed, children were asked to complete the same task back-to-back with the only change being the experimenter who carried out the joint task with the child. Furthermore, the joint Simon task was at the end of the testing session which lasted around 45 minutes in total (not including the PPVT). The analysis of task performance demonstrated that children responded quickly and accurately (see Table 1) on the second joint go/no-go task, which could be interpreted as counterevidence to the suggestion that the lack a joint Simon effect was due to decreased engagement. However, it could be that the children were not engaged beyond complying with basic instructions and therefore were not concerned with their co-actor's role in the task. Informally, the administrating experimenter noted that most children seemed bored with catching the same animal in all three go/no-go tasks. It is possible that children would have shown the joint Simon effect in the second joint condition if it was made more novel by having the child respond to the other stimulus or by changing the stimuli altogether.

More speculatively, the absence of a joint Simon effect the second time children completed the task may reflect that children have a limited capacity for joint action. As mentioned previously, an influential model of executive function suggests that it is a limited resource such that engaging in one activity that requires executive function impairs performance on a subsequent task that requires similar processes (Muraven & Baumeister, 2000). If the capacity for joint action in children is a limited resource, completing one joint task effortfully would be expected to lead to poorer joint engagement in a subsequent joint task. This suggestion could be more clearly examined by work in which the second joint task is different from the first.

Influence of Collaboration on the Joint Simon Effect

Existing work with adults suggests that the extent of the joint Simon effect is enhanced when participants are in an interdependent frame of mind such as after being primed with interdependent pronouns (Colzato et al., 2012) or when relying on their partner for a reward (Iani et al., 2011). Based on this work, it was expected that children in the collaborative group would show a larger joint Simon effect than children in the individual condition. As in the analysis of the motor contagion task, there was no evidence that the social manipulation modulated the overall magnitude of the joint Simon effect. Furthermore, for children in the collaborative condition there was no difference in the magnitude of the joint Simon effect when carrying out the task with the partner versus the observer from the social manipulation. This is inconsistent with the findings from the motor contagion task in which observing incongruent movements produced by the partner was associated with greater motor contagion.

The general finding that the joint Simon effect in children was insensitive to contextual influences may be attributed to the shared nature of the task. There is a large literature suggesting that young children have an intrinsic motivation to engage in social games. For example, it is known that children attempt to re-engage an experimenter when they suddenly stop participating in a joint activity (Ross & Lollis, 1987; Warneken et al., 2006; Warneken, Grafenhain, & Tomasello, 2012) even when the partner's actions are not essential (Grafenhain, Behne, Carpenter, & Tomasello, 2009). Considering this, children in the collaborative condition may have been equally interested in sharing the task with the observer as they were in sharing it with the experimenter who acted as their partner. Along similar lines, children in the individual condition may not be expected to show less interest in acting with the experimenter compared to children in the collaborative condition.

Influence of Collaboration on Response Inhibition

The final question addressed by the current study was how a collaborative social interaction influences children's overall executive function. One intriguing finding from work with adults is that some forms of social interaction facilitate performance on subsequent executive function tasks (Ybarra et al., 2008; Ybarra et al., 2011). Given successful social interaction is assumed to require executive functions, this boosting effect is thought to be due to a process of resource priming (Ybarra & Winkielman, 2012). In contrast to demanding social interactions that deplete executive function (e.g., Richeson & Shelton, 2003), relatively easier interactions are thought to increase the accessibility of these resources to the extent that the interaction engages processes that require executive functions (e.g., perspective taking). With this work in mind, we were interested in whether engaging in a collaboration, which is thought to require an element of inhibition, facilitated children's abilities to inhibit a prepotent response on subsequent tasks compared to working alone. Accuracy on the individual go/no-go task and the Simon task was used to address this question. Although all the tasks in our study required inhibitory control, these tasks did not involve a social component and therefore the results would not have been affected by differences in processing of social stimuli between the collaborative and individual conditions. The analyses of these tasks did not reveal any differences between the two conditions in task accuracy. Therefore, the prediction that collaboration would increase children's response inhibition was not supported.

One possibility for the lack of an effect is that the tasks used in this study were not optimal for examining general executive function. Since the individual go/no-go task was also used to examine the presence of a joint Simon effect, half the trials were go trials and half were no-go trials, which is consistent with existing work on the joint Simon task. However, go/no-go tasks that are primarily used to assess inhibitory control present the go stimulus more frequently so that the response becomes habitual and is therefore harder to suppress. Particularly important for our findings, previous work suggests that the go/no-go task is only difficult for preschool children when the go stimulus is presented at a higher frequency (Simpson & Riggs, 2006). Since children were seated on the right side of the screen in the current study, the go/no-go task still involved an element of inhibitory control since children had to inhibit the prepotent response to respond when a stimulus appears on the same side of the response button. However, it could be that suppressing this response was too easy to detect any differences in executive function between conditions. Consistent with this suggestion, children in the current study were extremely accurate on the task (i.e., 96.7%).

Considering this, it is possible that different tasks that are commonly used to assess response inhibition in children (e.g., day-night Stroop task, Luria's tapping task, less-is-more) may have detected an effect. While it would have been optimal to include one or two of these tasks in the current study, the protocol was already rather lengthy for children of this age (~45 minutes). It could also be that our social manipulation (~5 minutes) was too brief and did not engage executive processes long enough to increase short-term accessibility.

Conclusion

The aim of the present study was to examine how social factors influence executive function in preschool children. The results provide evidence that engaging in collaboration affects children's executive control processes in two ways. First, children's ability to inhibit imitating an observed action is reduced when the actions are produced by a former collaborative partner. Second, sharing a Simon task with another person influences children's executive processes compared to completing the same part of the task alone. The finding that a joint Simon effect was elicited when children shared a Simon task with another person informs theories about the mechanisms involved in children's joint action behaviors. Furthermore, it opens up new opportunities to study executive function in a social context, which would have significant implications for basic applied work.

REFERENCES CITED

Adolphs, R. (2003). Cognitive neuroscience of human social behaviour. *Nature Reviews Neuroscience, 4*, 165-178.

Ashley, J., & Tomasello, M. (1998). Cooperative problem solving and teaching in preschoolers. *Social Development, 7*, 143-163.

Atmaca, S., Sebanz, N., Prinz, W., & Knoblich, G. (2008). Action co-representation: The joint SNARC effect. *Social Neuroscience, 3*, 410-420.

Barresi, J., & Moore, C. (1996). Intentional relations and social understanding. *Behavioral and Brain Sciences, 19*, 107-122.

Baumeister, R. F., Bratslavsky, E., Muraven, M., & Tice, D. M. (1998). Ego depletion: Is the active self a limited resource? *Journal of Personality and Social Psychology, 74*, 1252-1265.

Baumeister, R. F., Muraven, M., & Tice, D. M. (2000). Ego depletion: A resource model of volition, self-regulation, and controlled processing. *Social Cognition, 18*, 130-150.

Blair, C., & Razza, R. P. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development, 78*, 647-663.

Blakemore, S. J., & Frith, C. (2005). The role of motor contagion in the prediction of action. *Neuropsychologia, 43*, 260-267.

Bouquet, C. A., Gaurier, V., Shipley, T., Toussaint, L., & Blandin, Y. (2007). Influence of the perception of biological or non-biological motion on movement execution. *Journal of Sports Sciences, 25*, 519-530.

Brass, M., Bekkering, H., & Prinz, W. (2001). Movement observation affects movement execution in a simple response task. *Acta Psychologica, 106*, 3-22.

Brass, M., Bekkering, H., Wohlschlager, A., & Prinz, W. (2000). Compatibility between observed and executed finger movements: Comparing symbolic, spatial, and imitative cues. *Brain and Cognition, 44*, 124-143.

Bronson, M. B. (2000). *Self-regulation in early childhood: Nature and nurture*. New York: Guilford.

Brownell, C. A. (2011). Early Developments in Joint Action. *Review of Philosophy and Psychology, 2*, 193-211.

Bryck, R. L., & Fisher, P. A. (2012). Training the brain: Practical applications of neural plasticity from the intersection of cognitive neuroscience, developmental psychology, and prevention science. *American Psychologist, 67*, 87-100.

Ciairano, S., Visu-Petra, L., & Settanni, M. (2007). Executive inhibitory control and cooperative behavior during early school years: A follow-up study. *Journal of Abnormal Child Psychology, 35*, 335-345.

Clark, S., Tremblay, F., & Ste-Marie, D. (2004). Differential modulation of corticospinal excitability during observation, mental imagery and imitation of hand actions. *Neuropsychologia, 42*, 105-112.

Colzato, L. S., de Bruijn, E. R., & Hommel, B. (2012). Up to "me" or up to "us"? The impact of self-construal priming on cognitive self-other integration. *Frontiers in Psychology, 3*, 341.

Cook, J., & Bird, G. (2011). Social attitudes differentially modulate imitation in adolescents and adults. *Experimental Brain Research, 211*, 601-612.

Cook, J. L., & Bird, G. (2012). Atypical social modulation of imitation in autism spectrum conditions. *Journal of Autism and Developmental Disorders, 42*, 1045-1051.

Cooper, C. R. (1980). Development of collaborative problem-solving among preschool children. *Developmental Psychology, 16*, 433-440.

Craft, J. L., & Simon, J. R. (1970). Processing symbolic information from a visual display: Interference from an irrelevant directional cue. *Journal of Experimental Psychology, 83*, 415-420.

Davidson, M. C., Amso, D., Anderson, L. C., & Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: Evidence from manipulations of memory, inhibition, and task switching. *Neuropsychologia, 44*, 2037-2078.

De Jong, R., Liang, C. C., & Lauber, E. (1994). Conditional and unconditional automaticity: A dual-process model of effects of spatial stimulus-response correspondence. *Journal of Experimental Psychology: Human Perception and Performance, 20*, 731-750.

Decety, J., Jackson, P. L., Sommerville, J. A., Chaminade, T., & Meltzoff, A. N. (2004). The neural bases of cooperation and competition: An fMRI investigation. *NeuroImage, 23*, 744-751.

Diamond, A., Barnett, W. S., Thomas, J., & Munro, S. (2007). Preschool program improves cognitive control. *Science, 318*, 1387-1388.

Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science, 333*, 959-964.

Diamond, A., & Taylor, C. (1996). Development of an aspect of executive control: Development of the abilities to remember what I said and to "do as I say, not as I do". *Developmental Psychobiology, 29*, 315-334.

Dolk, T., Hommel, B., Prinz, W., & Liepelt, R. (2013). The (not so) social Simon effect: A referential coding account. *Journal of Experimental Psychology: Human Perception and Performance, 39*, 1248-1260.

Dunn, L. M., & Dunn, L. M. (1997). *Peabody picture vocabulary test (third ed.)*. Circle Pines, MN: American Guidance Service.

Dunning, D. L., Holmes, J., & Gathercole, S. E. (2013). Does working memory training lead to generalized improvements in children with low working memory? A randomized controlled trial. *Developmental Science, 16*, 915-925.

Fadiga, L., Fogassi, L., Pavesi, G., & Rizzolatti, G. (1995). Motor facilitation during action observation: A magnetic stimulation study. *Journal of Neurophysiology, 73*, 2608-2611.

Farran, D., Wilson, S., & Lipsey, M. (2013). *Effects of a curricular attempt to improve self-regulation and achievement in prekindergarten children.* Paper presented at the Society for Research in Child Development. Seattle, WA.

Ferraro, L., Iani, C., Mariani, M., Milanese, N., & Rubichi, S. (2011). Facilitation and interference components in the joint Simon task. *Experimental Brain Research, 211*, 337-343.

Finkel, E. J., Campbell, W. K., Brunell, A. B., Dalton, A. N., Scarbeck, S. J., & Chartrand, T. L. (2006). High-maintenance interaction: Inefficient social coordination impairs self-regulation. *Journal of Personality and Social Psychology, 91*, 456-475.

Foley, M. A., Passalacqua, C., & Ratner, H. H. (1993). Appropriating the actions of another: Implications for children's learning and memory. *Cognitive Development, 8*, 373–401.

Foley, M. A., & Ratner, H. H. (1998). Children's recoding in memory for collaboration: A way of learning from others. *Cognitive Development, 13*, 91-108.

Ford, R. M., Lobao, S. N., Macaulay, C., & Herdman, L. M. (2011). Empathy, theory of mind, and individual differences in the appropriation bias among 4- and 5-year-olds. *Journal of Experimental Child Psychology, 110*, 626-646.

Gangitano, M., Mottaghy, F. M., & Pascual-Leone, A. (2001). Phase-specific modulation of cortical motor output during movement observation. *NeuroReport, 12*, 1489-1492.

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin, 134*, 31-60.

Gathercole, S. E., & Pickering, S. J. (2000). Working memory deficits in children with low achievements in the national curriculum at 7 years of age. *British Journal of Educational Psychology, 70 (Pt 2)*, 177-194.

Giannotta, F., Burk, W. J., & Ciairano, S. (2011). The role of inhibitory control in children's cooperative behaviors during a structured puzzle task. *Journal of Experimental Child Psychology, 110*, 287-298.

Grafenhain, M., Behne, T., Carpenter, M., & Tomasello, M. (2009). Young children's understanding of joint commitments. *Developmental Psychology, 45*, 1430-1443.

Hala, S., & Russell, J. (2001). Executive control within strategic deception: A window on early cognitive development? *Journal of Experimental Child Psychology, 80*, 112-141.

Hollander, A., Jung, C., & Prinz, W. (2011). Covert motor activity on NoGo trials in a task sharing paradigm: Evidence from the lateralized readiness potential. *Experimental Brain Research, 211*, 345-356.

Holmes, J., Gathercole, S. E., & Dunning, D. L. (2009). Adaptive training leads to sustained enhancement of poor working memory in children. *Developmental Science, 12*, F9-15.

Hommel, B., Colzato, L. S., & van den Wildenberg, W. P. (2009). How social are task representations? *Psychological Science, 20*, 794-798.

Iani, C., Anelli, F., Nicoletti, R., Arcuri, L., & Rubichi, S. (2011). The role of group membership on the modulation of joint action. *Experimental Brain Research, 211*, 439-445.

Jeannerod, M. (2001). Neural simulation of action: A unifying mechanism for motor cognition. *NeuroImage, 14*, S103-S109.

Kidd, C., Palmeri, H., & Aslin, R. N. (2013). Rational snacking: Young children's decision-making on the marshmallow task is moderated by beliefs about environmental reliability. *Cognition, 126*, 109-114.

Kilner, J. M., Hamilton, A. F., & Blakemore, S. J. (2007). Interference effect of observed human movement on action is due to velocity profile of biological motion. *Social Neuroscience, 2*, 158-166.

Kilner, J. M., Paulignan, Y., & Blakemore, S. J. (2003). An interference effect of observed biological movement on action. *Current Biology, 13*, 522-525.

Kirschner, S., & Tomasello, M. (2010). Joint music making promotes prosocial behavior in 4-year-old children. *Evolution and Human Behavior, 31*, 354-364.

Klingberg, T., Fernell, E., Olesen, P. J., Johnson, M., Gustafsson, P., Dahlstrom, K., et al. (2005). Computerized training of working memory in children with ADHD--a randomized, controlled trial. *Journal of the American Academy of Child and Adolescent Psychiatry, 44*, 177-186.

Knoblich, G., & Sebanz, N. (2006). The social nature of perception and action. *Current Directions in Psychological Science, 15*, 99-104.

Kourtis, D., Knoblich, G., & Sebanz, N. (2013). History of interaction and task distribution modulate action simulation. *Neuropsychologia, 51*, 1240-1247.

Landry, S. H., & Smith, K. E. (2010). Early social and cognitive precursors and parental support for self-regulation and executive function: Relations from early childhood into adolescence. In J. Carpendale, G. Iarocci, U. Muller, B. Sokol & A. Young (Eds.), *Self and social regulation: Social interaction and the development of social understanding and executive functions* (pp. 386-417). Oxford: Oxford University Press.

Leighton, J., Bird, G., Orsini, C., & Heyes, C. (2010). Social attitudes modulate automatic imitation. *Journal of Experimental Social Psychology, 46*, 905-910.

Lewis, C., & Carpendale, J. I. M. (2009). Introduction: Links between social interaction and executive function. *Social interaction and the development of executive function, 123*, 1-15.

Lu, C.-H., & Proctor, R. W. (1995). The influence of irrelevant location information on performance: A review of the Simon and spatial Stroop effects. *Psychonomic Bulletin & Review, 2*, 174-207.

Marshall, P. J., Bouquet, C. A., Thomas, A. L., & Shipley, T. F. (2010). Motor contagion in young children: Exploring social influences on perception-action coupling. *Neural Networks, 23*, 1017-1025.

Martin-Rhee, M. M., & Bialystok, E. (2008). The development of two types of inhibitory control in monolingual and bilingual children. *Bilingualism: Language and Cognition, 11*, 81-93.

Melby-Lervag, M., & Hulme, C. (2013). Is working memory training effective? A meta-analytic review. *Developmental Psychology, 49*, 270-291.

Meyer, M., Bekkering, H., Paulus, M., & Hunnius, S. (2010). Joint action coordination in 2(1/2)- and 3-year-old children. *Frontiers in Human Neuroscience, 4*, 220.

Mischel, W., Ayduk, O., Berman, M. G., Casey, B. J., Gotlib, I. H., Jonides, J., et al. (2011). 'Willpower' over the life span: Decomposing self-regulation. *Social Cognitive and Affective Neuroscience, 6*, 252-256.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "Frontal Lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*, 49-100.

Moffitt, T. E., Arseneault, L., Belsky, D., Dickson, N., Hancox, R. J., Harrington, H., et al. (2011). A gradient of childhood self-control predicts health, wealth, and public safety. *Proceedings of the National Academy of Sciences of the United States of America, 108*, 2693-2698.

Molenberghs, P., Cunnington, R., & Mattingley, J. B. (2012). Brain regions with mirror properties: A meta-analysis of 125 human fMRI studies. *Neuroscience and Biobehavioral Reviews, 36*, 341-349.

Muraven, M., & Baumeister, R. F. (2000). Self-regulation and depletion of limited resources: Does self-control resemble a muscle? *Psychological Bulletin, 126*, 247-259.

Muraven, M., Tice, D. M., & Baumeister, R. F. (1998). Self-control as limited resource: Regulatory depletion patterns. *Journal of Personality and Social Psychology, 74*, 774-789.

Ponitz, C. C., McClelland, M. M., Matthews, J. S., & Morrison, F. J. (2009). A structured observation of behavioral self-regulation and its contribution to kindergarten outcomes. *Developmental Psychology, 45*, 605-619.

Press, C., Bird, G., Flach, R., & Heyes, C. (2005). Robotic movement elicits automatic imitation. *Brain Research. Cognitive Brain Research, 25*, 632-640.

Prinz, W. (1997). Perception and action planning. *European Journal of Cognitive Psychology, 9*, 129-154.

Przyrembel, M., Smallwood, J., Pauen, M., & Singer, T. (2012). Illuminating the dark matter of social neuroscience: Considering the problem of social interaction from philosophical, psychological, and neuroscientific perspectives. *Frontiers in Human Neuroscience, 6*, 190.

Qu, L. (2011). Two is better than one, but mine is better than ours: Preschoolers' executive function during co-play. *Journal of Experimental Child Psychology, 108*, 549-566.

Raver, C. C., Jones, S. M., Li-Grining, C., Zhai, F., Bub, K., & Pressler, E. (2011). CSRP's Impact on low-income preschoolers' preacademic skills: Self-regulation as a mediating mechanism. *Child Development, 82*, 362-378.

Raver, C. C., Jones, S. M., Li-Grining, C. P., Metzger, M., Smallwood, K., & Sardin, L. (2008). Improving Preschool Classroom Processes: Preliminary Findings from a Randomized Trial Implemented in Head Start Settings. *Early Childhood Research Quarterly, 63*, 253-255.

Richeson, J., & Shelton, J. N. (2003). When Prejudice Does Not Pay: Effects of Interracial Contact on Executive Function. *Psychological Science, 14*, 287-290.

Richeson, J. A., & Trawalter, S. (2005). Why do interracial interactions impair executive function? A resource depletion account. *Journal of Personality and Social Psychology, 88*, 934-947.

Riggs, N. R., Greenberg, M. T., Kusche, C. A., & Pentz, M. A. (2006). The mediational role of neurocognition in the behavioral outcomes of a social-emotional prevention program in elementary school students: Effects of the PATHS Curriculum. *Prevention Science, 7*, 91-102.

Ross, H. S., & Lollis, S. P. (1987). Communication within infant social games. *Developmental Psychology, 23*, 241-248.

Sebanz, N., Bekkering, H., & Knoblich, G. (2006a). Joint action: Bodies and minds moving together. *Trends in Cognitive Sciences, 10*, 70-76.

Sebanz, N., Knoblich, G., & Prinz, W. (2003). Representing others' actions: Just like one's own? *Cognition, 88*, B11-21.

Sebanz, N., Knoblich, G., Prinz, W., & Wascher, E. (2006b). Twin peaks: An ERP study of action planning and control in co-acting individuals. *Journal of Cognitive Neuroscience, 18*, 859-870.

Simon, J. R. (1969). Reactions toward the source of stimulation. *Journal of Experimental Psychology, 81*, 174-176.

Simpson, A., & Riggs, K. J. (2006). Conditions under which children experience inhibitory difficulty with a "button-press" go/no-go task. *Journal of Experimental Child Psychology, 94*, 18-26.

Sokol, B. W., Muller, U., Carpendale, J., Young, A., & Iarocci, G. (Eds.). (2010). *Self and social regulation: Social interaction and the development of social understanding and executive functions*. New York: Oxford University Press.

Sommerville, J. A., & Hammond, A. J. (2007). Treating another's actions as one's own: Children's memory of and learning from joint activity. *Developmental Psychology, 43*, 1003-1018.

Spengler, S., Brass, M., Kuhn, S., & Schutz-Bosbach, S. (2010). Minimizing motor mimicry by myself: self-focus enhances online action-control mechanisms during motor contagion. *Consciousness and Cognition, 19*, 98-106.

St. Clair-Thompson, H. L., Stevens, R., Hunt, A., & Bolder, E. (2010). Improving children’s working memory and classroom performance. *Educational Psychology, 30*.

Stanley, J., Gowen, E., & Miall, R. C. (2007). Effects of agency on movement interference during observation of a moving dot stimulus. *Journal of Experimental Psychology: Human Perception and Performance, 33*, 915-926.

Thorell, L. B., Lindqvist, S., Bergman Nutley, S., Bohlin, G., & Klingberg, T. (2009). Training and transfer effects of executive functions in preschool children. *Developmental Science, 12*, 106-113.

Tomasello, M., Carpenter, M., Call, J., Behne, T., & Moll, H. (2005). Understanding and sharing intentions: The origins of cultural cognition. *Behavioral and Brain Sciences, 28*, 675-691; discussion 691-735.

Tsai, C. C., Kuo, W. J., Hung, D. L., & Tzeng, O. J. (2008). Action co-representation is tuned to other humans. *Journal of Cognitive Neuroscience, 20*, 2015-2024.

Tsai, C. C., Kuo, W. J., Jing, J. T., Hung, D. L., & Tzeng, O. J. (2006). A common coding framework in self-other interaction: Evidence from joint action task. *Experimental Brain Research, 175*, 353-362.

Tsujimoto, S. (2008). The prefrontal cortex: Functional neural development during early childhood. *Neuroscientist, 14*, 345-358.

van Baaren, R. B., Maddux, W. W., Chartrand, T. L., de Bouter, C., & van Knippenberg, A. (2003). It takes two to mimic: Behavioral consequences of self-construals. *Journal of Personality and Social Psychology, 84*, 1093-1102.

Vlainic, E., Liepelt, R., Colzato, L. S., Prinz, W., & Hommel, B. (2010). The Virtual Co-Actor: The Social Simon Effect does not Rely on Online Feedback from the Other. *Frontiers in Psychology, 1*, 208.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Warneken, F., Chen, F., & Tomasello, M. (2006). Cooperative activities in young children and chimpanzees. *Child Development, 77*, 640-663.

Warneken, F., Grafenhain, M., & Tomasello, M. (2012). Collaborative partner or social tool? New evidence for young children's understanding of joint intentions in collaborative activities. *Developmental Science, 15*, 54-61.

Welsh, T. N., Higgins, L., Ray, M., & Weeks, D. J. (2007). Seeing vs. believing: Is believing sufficient to activate the processes of response co-representation? *Human Movement Science, 26*, 853-866.

Ybarra, O., Burnstein, E., Winkielman, P., Keller, M. C., Manis, M., Chan, E., et al. (2008). Mental exercising through simple socializing: Social interaction promotes general cognitive functioning. *Personality and Social Psychology Bulletin, 34*, 248-259.

Ybarra, O., & Winkielman, P. (2012). On-line social interactions and executive functions. *Frontiers in Human Neuroscience, 6*, 75.

Ybarra, O., Winkielman, P., Yeh, I., Burnstein, E., & Kavanagh, L. (2011). Friends (and sometimes enemies) with cognitive benefits: What types of social interactions boost executive functioning? *Social Psychological and Personality Science, 2*, 253-261.

Zelazo, P. D., Muller, U., Frye, D., Marcovitch, S., Argitis, G., Boseovski, J., et al. (2003). The development of executive function in early childhood. *Monographs of the Society for Research in Child Development, 68*, vii-137.

APPENDIX A

SCRIPTS FROM THE SOCIAL MANIPULATION

For the collaborative condition:

1. At approximately 1 minute:
   Experimenter 2*: "I am glad we are doing this *together"*
   Experimenter 3*: "You're both doing a great job"

2. At approximately 2 minutes:
   Experimenter 3: "You guys are half way there"
   Experimenter 2: "You are a great partner"

3. At approximately 3 minutes:
   Experimenter 2: "*We* will be finished soon"
   Experimenter 3: "You're almost finished"

4. When the child is finished:
   Experimenter 3: "Good job!"
   Experimenter 2: "*We* made a good *team*"

For the individual condition:

1. At approximately 1 minute:
   Experimenter 2: "You're doing a great job all by yourself"
   Experimenter 3: "Yea keep it up"

2. At approximately 2 minutes:
   Experimenter 3: "*You* got half the balls in the bucket"
   Experimenter 2: "Only __ left"

3. At approximately 3 minutes:
   Experimenter 2: "Good job___"
   Experimenter 3: "You're almost finished"

4. When the child is finished:
   Experimenter 3: "You did it all by yourself"
   Experimenter 2: "Yea, you got it on your own

*For the collaborative condition, Experimenter 2 is the partner and Experimenter 3 is the observer

APPENDIX B

VIDEO ORDERS MOTOR CONTAGION TASK

Order 1
1. Experimenter 2* Incongruent
2. Experimenter 3* Incongruent
3. Blank Screen
4. Experimenter 2 Congruent
5. Experimenter 3 Incongruent
6. Experimenter 2 Congruent
7. Blank Screen
8. Experimenter 3 Congruent
9. Experimenter 3 Congruent
10. Experimenter 2 Incongruent

Order 2
1. Experimenter 2 Incongruent
2. Blank Screen
3. Experimenter 2 Incongruent
4. Experimenter 3 Incongruent
5. Experimenter 3 Congruent
6. Experimenter 3 Congruent
7. Experimenter 3 Incongruent
8. Experimenter 2 Congruent
9. Blank Screen
10. Experimenter 2 Congruent

Order 3
1. Blank Screen
2. Experimenter 3 Congruent
3. Experimenter 2 Incongruent
4. Experimenter 3 Incongruent
5. Experimenter 2 Incongruent
6. Blank Screen
7. Experimenter 2 Congruent
8. Experimenter 3 Incongruent
9. Experimenter 3 Congruent
10. Experimenter 2 Congruent

Order 4
1. Experimenter 2 Incongruent
2. Experimenter 3 Congruent
3. Experimenter 2 Congruent
4. Experimenter 3 Incongruent

5. Experimenter 2 Congruent
6. Experimenter 3 Incongruent
7. Blank Screen
8. Experimenter 3 Congruent
9. Blank Screen
10. Experimenter 2 Incongruent

Order 5

1. Experimenter 3 Incongruent
2. Experimenter 2 Congruent
3. Experimenter 2 Incongruent
4. Blank Screen
5. Experimenter 2 Incongruent
6. Experimenter 3 Congruent
7. Experimenter 2 Congruent
8. Experimenter 3 Congruent
9. Blank Screen
10. Experimenter 3 Incongruent

Order 6

1. Experimenter 3 Incongruent
2. Blank Screen
3. Experimenter 2 Congruent
4. Experimenter 2 Incongruent
5. Blank Screen
6. Experimenter 3 Congruent
7. Experimenter 2 Congruent
8. Experimenter 3 Congruent
9. Experimenter 2 Incongruent
10. Experimenter 3 Incongruent

Order 7

1. Experimenter 2 Incongruent
2. Experimenter 2 Congruent
3. Blank Screen
4. Experimenter 3 Congruent
5. Experimenter 3 Congruent
6. Experimenter 3 Incongruent
7. Blank Screen
8. Experimenter 2 Congruent
9. Experimenter 2 Incongruent
10. Experimenter 3 Incongruent

Order 8

1. Blank Screen
2. Experimenter 2 Incongruent
3. Experimenter 2 Congruent
4. Experimenter 3 Incongruent
5. Experimenter 3 Congruent
6. Blank Screen
7. Experimenter 2 Congruent
8. Experimenter 2 Incongruent
9. Experimenter 3 Congruent
10. Experimenter 3 Incongruent

Order 9

1. Experimenter 3 Incongruent
2. Experimenter 2 Incongruent
3. Blank Screen
4. Experimenter 3 Congruent
5. Experimenter 2 Incongruent
6. Experimenter 3 Congruent
7. Blank Screen
8. Experimenter 2 Congruent
9. Experimenter 2 Congruent
10. Experimenter 3 Incongruent

Order 10

1. Experimenter 3 Incongruent
2. Blank Screen
3. Experimenter 3 Incongruent
4. Experimenter 2 Incongruent
5. Experimenter 2 Congruent
6. Experimenter 2 Congruent
7. Experimenter 2 Incongruent
8. Experimenter 3 Congruent
9. Blank Screen
10. Experimenter 3 Congruent

Order 11

1. Blank Screen
2. Experimenter 2 Congruent
3. Experimenter 3 Incongruent
4. Experimenter 2 Incongruent
5. Experimenter 3 Incongruent
6. Blank Screen
7. Experimenter 3 Congruent

8. Experimenter 2 Incongruent
9. Experimenter 2 Congruent
10. Experimenter 3 Congruent

Order 12

1. Experimenter 3 Incongruent
2. Experimenter 2 Congruent
3. Experimenter 3 Congruent
4. Experimenter 2 Incongruent
5. Experimenter 3 Congruent
6. Experimenter 2 Incongruent
7. Blank Screen
8. Experimenter 2 Congruent
9. Blank Screen
10. Experimenter 3 Incongruent

Order 13

1. Experimenter 2 Incongruent
2. Experimenter 3 Congruent
3. Experimenter 3 Incongruent
4. Blank Screen
5. Experimenter 3 Incongruent
6. Experimenter 2 Congruent
7. Experimenter 3 Congruent
8. Experimenter 2 Congruent
9. Blank Screen
10. Experimenter 2 Incongruent

Order 14

1. Experimenter 2 Incongruent
2. Blank Screen
3. Experimenter 3 Congruent
4. Experimenter 3 Incongruent
5. Blank Screen
6. Experimenter 2 Congruent
7. Experimenter 3 Congruent
8. Experimenter 2 Congruent
9. Experimenter 3 Incongruent
10. Experimenter 2 Incongruent

*For the collaborative condition, Experimenter 2 is the partner and Experimenter 3 is the observer