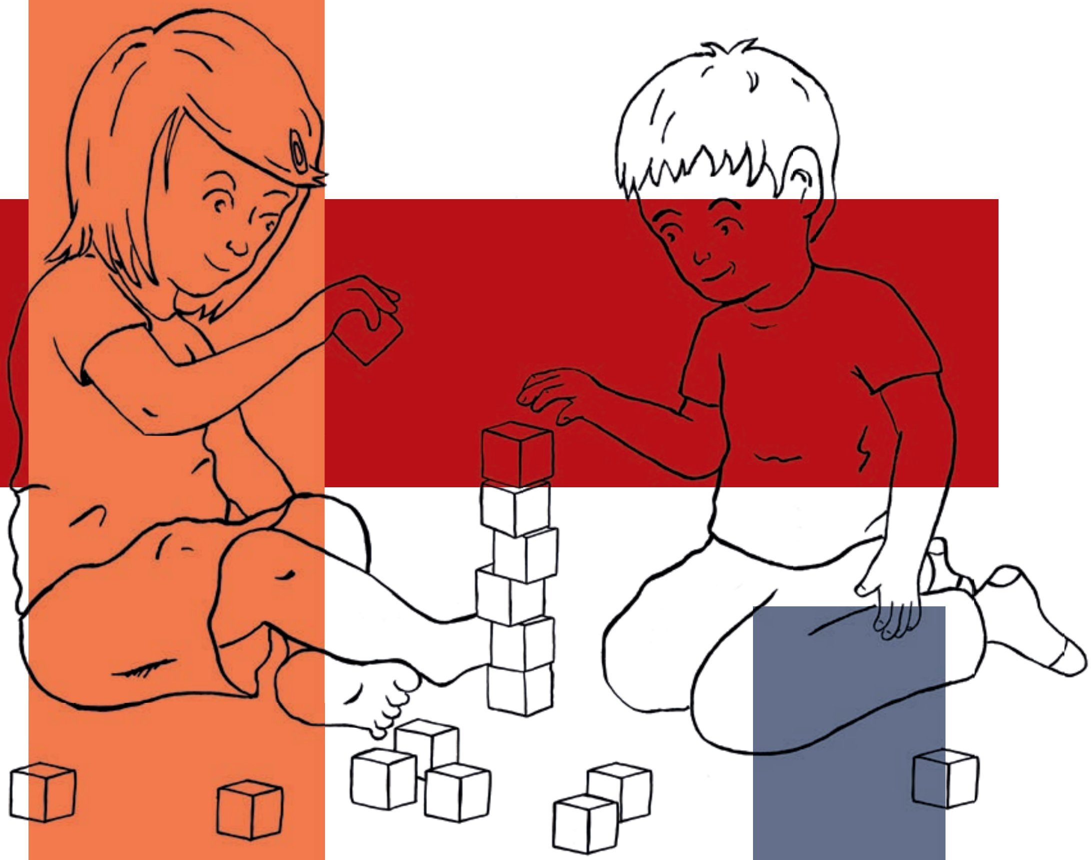
Peer Interaction Under Construction



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Hinke M. Endedijk

Peer Interaction Under Construction

Hinke M. Endedijk

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Promotoren
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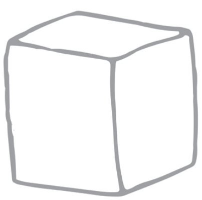
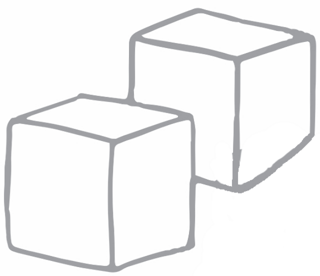




General Introduction

Imagine yourself sitting in the audience during a concert of a string quartet. The musicians enter the stage and take their seats. The viola player picks up some of the cello player's fallen sheet music and gives it back. The audience quickly becomes quiet. The musicians concentrate, look at each other, take a deep breath together, and then, at exactly the same time, they play the first chord. The music develops into different rhythms and tempi, but piece after piece the ensemble manages to give a high-quality performance. At the end of the concert you give a big round of applause, together with the rest of the audience.

This is one example of the many different social interactions we face in everyday life. Interactions are social exchanges "in which the participants' actions are interdependent such that each actor's behavior is both a response to, and stimulus for, the other participant's behavior" (Rubin, Bukowski, & Parker, 2006, p. 576). Most prominent are the different interactive behaviors by which we influence the way our interaction partner acts in response. Interactive behaviors can be divided into affiliative and antagonistic behaviors (Vaughn & Santos, 2009). Affiliative behaviors are behaviors that support the course of the interaction and stimulate positive responses from our partner, such as in the above example the viola player that helped the cello player with his music. Instead, the viola player could also have responded more antagonistically to the cello player for example by sighing or making a negative comment. In this case, the course of the interaction could have developed more negatively. The quality of social interactions thus can be described in terms of the frequency with which affiliative and antagonistic behaviors occur.

We also influence our partners' behavior via interpersonal action coordination. In the example of the string quartet, the musicians started playing at the same time by adapting their actions to each other, such as taking a deep breath together and lifting their bow before touching the strings. Interpersonal coordination can be quantified by the degree to which actions in an interaction of two or more people follow a certain pattern or are synchronized (Bernieri & Rosenthal, 1991). When at least one person adjusts his or her actions to the action of another person, interpersonal coordination is present (Cacioppo et al., 2014). For most social interactions, interpersonal coordination is necessary, or at least facilitatory: playing a team sport, dancing or making music, having a conversation, and helping others lift a heavy object.

Given its central role in social interaction, it is surprising that we know little about how exactly interpersonal coordination develops in early childhood, although it has been studied frequently in adults (Chartrand & Lakin, 2013; Lakin, 2012; Repp & Su, 2013; Schmidt & Richardson, 2008). If interpersonal coordination has been studied in children, research has focused mainly on their interactions with adults (cf. Kirschner & Tomasello, 2009; Meyer, Bekkering, Paulus, & Hunnius, 2010). Although interesting, as adults are skillful and predictable partners, it is unclear how much these interactions tell us about children's regular interpersonal coordination with peers who are variable in their behavior and less proficient. The study of interpersonal coordination during peer interaction could enrich our knowledge of the development of interpersonal coordination in early childhood, its interplay with interaction quality, and its role in social development.

DEVELOPMENT OF PEER INTERACTION

As early as 2 months of age, peer interaction begins to emerge with heightened interest in other children and mutual visual contact that extends to frequent vocalizations and mutual touches during the course of the first year (Eckerman, Whatley, & Kutz, 1975; Field, 1979; Fogel, 1979). Peer interaction becomes more prominent in play situations of 2-year-olds, not necessarily due to an increase in peer interaction, but due to a decrease in interaction with caregivers (Gevers Deynoot-Schaub & Riksen-Walraven, 2006). Moreover, 2-year-old children are able to engage in prolonged interactions with other children (Viernickel, 2009).

Not only do children spend more time interacting with peers over the years, their interactions also gain complexity. While in the first few months after birth peer interaction mainly consists of visual contact and touches, children regularly interact with peers via toys by the end of their first year (Eckerman et al., 1975). Shortly after their first birthday, affiliative and antagonistic behaviors become important, as they influence the probability that the peers will respond to each other's overtures (Williams, Ontai, & Mastergeorge, 2010). For example, offering an object resulted in a response 80 percent of the time, while trying to take the object or touching the peer's object resulted in a response from a peer only 14 and 30 percent of the time, respectively. Moreover, during their second year children regularly show imitative behaviors that set the stage for first games such as leader–follower games (Eckerman, Davis, & Didow, 1989). These imitative games transform into purposeful and jointly regulated behavior coordination around 24 months, such as cooperation and collaborative problem solving (Eckerman & Peterman, 2004). This quick development results in peer interaction during toddlerhood characterized by the coordination of actions and frequent use of affiliative and antagonistic behaviors (Rubin et al., 2006).

Interestingly, during this rapid development in children's peer interaction, the constellations are very stable. Throughout early childhood, play in dyads remains the most important form of peer interaction (Ladd, Price, & Hart, 2001; Viernickel, 2009), although from the age of 4 boys will begin to play additionally in triads and larger groups (Benenson, Apostoleris, & Parnass, 1997). As children's play is predominantly characterized by dyadic contacts, the focus of this thesis was on the development of dyadic peer interaction.

DEVELOPMENT OF INTERACTION QUALITY

Significant advances are made in the quality of children's peer interactions as indicated by a change in the frequencies with which affiliative and antagonistic behaviors occur. An example of affiliative behavior is the viola player readily helping the cello player to pick up his music. Different forms of affiliative behaviors emerge by the beginning of the second year of life, when infants start to help adults in simple tasks like handing over objects out of reach (Warneken, Hare, Melis, Hanus, & Tomasello, 2007). Over the preschool period, affiliative behaviors, such as sharing, helping and comforting, become more common (Rubin et al., 2006; Zahn-Waxler & Smith, 1992).

The opposite of affiliative behaviors are antagonistic behaviors, such as taking away toys, claiming or displaying aggression. Most antagonistic behaviors occur during struggles over play material (Coplan & Arbeau, 2009; Eckerman & Peterman, 2004). Although they are common in young children, they occur less frequently than affiliative behaviors, and struggles are often brief and account for only a small proportion of the time with peers (Eckerman & Peterman, 2004). As antagonistic behaviors receive fewer peer responses than affiliative behaviors, this lack of success in generating social reciprocity may provide children with important information on how to successfully develop interactions with peers (Williams et al., 2010). This possibly explains why the frequency of antagonistic behaviors increases until the age of 2 to 3 years, after which it declines (e.g., Dodge, Coie, & Lynam, 2006; NICHD Early Child Care Research Network, 2004b). During this decline, the nature of preschoolers' conflicts change as they begin to display more subtle forms of antagonistic behaviors, such as social and relational aggression (Crick, Casas, & Mosher, 1997). Triggers for conflicts change from division of objects to differences in play and ideas (Coplan & Arbeau, 2009; Eckerman & Peterman, 2004).

In addition to this developmental change in general interaction quality, children also begin to adapt their behaviors to the situation at hand. Already 2-year-olds are able to adjust both the content and the complexity of their social behavior to the age of their partners, for example by slowing down their overtures (Brownell, 1990; Stolk, Hunnius, Bekkering, & Toni, 2013). Moreover, by 3 years, children advise others to be generous towards partners who have shared before (Olson & Spelke, 2008), or increase their own affiliative behavior towards people when they had previously helped them or shared with them (Warneken & Tomasello, 2013), hence adjusting their behavior based on past experience with the partner. And from the age of 5 children increasingly share with a partner who could potentially reciprocate (Engelmann, Over, Herrmann, & Tomasello, 2013; Sebastián-Enesco & Warneken, 2015). Further, preschool children begin to adapt their social behavior to social norms and rules (e.g., 'we take turns when we play together'; Warneken & Tomasello, 2009). Thus, over the course of early childhood, children become more flexible in adapting the frequency of affiliative and antagonistic behaviors to the interaction partner.

There also are large interindividual differences between children in the frequency of their interactive behaviors with peers. Whereas initially children who show more affiliative behaviors also show more antagonistic behaviors (Williams, Ontai, & Mastergeorge, 2007), this association weakens in the second year, and differences in interaction styles begin to emerge with some children mainly showing positive interaction patterns, and other children dominantly showing negative interactions (Gevers Deynoot-Schaub & Riksen-Walraven, 2006). Socially competent children are able to achieve a balance between meeting their own needs and maintaining positive relations with peers (Green & Rechis, 2006).

Together with the large variety between children and between interactions, children also show continuity in their behavior (e.g., Eisenberg et al., 1999; Fabes, Martin, & Hanish, 2009; Williams et al., 2007). Children's tendency to display antagonistic behaviors in particular is stable over time (Gevers Deynoot-Schaub & Riksen-Walraven, 2006; Howes & Phillipsen, 1998; NICHD Early Child Care Research Network, 2001). Interaction behavior styles – once acquired – may have significant consequences for subsequent development, as the acquired skills lay the foundation for more complex interactions such as solving conflict and social problems (Howes & Phillipsen, 1998).

DEVELOPMENT OF INTERPERSONAL COORDINATION

Forms of interpersonal coordination

Being able to successfully coordinate actions with another person also plays a role during social interaction. Remember the example of the musicians breathing together, lifting their bow together and starting to play at exactly the same time. In this example interpersonal coordination was planned: The players intended to start at the same time to produce the combined melody. But interpersonal coordination also can occur spontaneously. In the example, the audience applauded at the end of the concert. While everyone claps in a different tempo as his or her neighbor in the beginning, the clapping of the group becomes coordinated after a short time and soon the entire audience applauds in the same rhythm (Néda, Ravasz, Brechet, Vicsek, & Barabasi, 2000). These two forms of interpersonal coordination are known as planned and emergent coordination (Knoblich, Butterfill, & Sebanz, 2011).

During planned coordination, the agents' behavior is driven by the intended joint outcome of the actions (Knoblich et al., 2011), usually in the context of a specific task (Sebanz, Bekkering, & Knoblich, 2006). This description overlaps with the definition of cooperation, which is coordination of behavior to achieve a common goal (cf. Brownell, Ramani, & Zerwas, 2006; Coplan & Arbeau, 2009; Warneken, Chen, & Tomasello, 2006). Cooperation is the term applied most frequently to describe coordinated interactions in the developmental psychology literature and will be used throughout this thesis. Children cooperate regularly with peers during everyday play. During cooperation the individuals' actions can be imitative, such as building a block tower together by placing blocks in alternating turns. Actions can also be complementary, for example, when one child holds the block tower so that the other child can place a block. To be successful at cooperation, a certain amount of planning is required to reach the common goal (Brownell & Carriger, 1990). Therefore, shared task representations (Knoblich et al., 2011) or shared intentions are important (Liebal, Colombi, Rogers, Warneken, & Tomasello, 2008; Tomasello, Carpenter, Behne, & Moll, 2005), as in this example that they are building a tower and know of each other that they want to build a block tower. Moreover, during the building of the block tower the children have to monitor each other, predict each other's actions (Meyer, Hunnius, van Elk, van Ede, & Bekkering, 2011; Vesper, Butterfill, Knoblich, & Sebanz, 2010), and adapt their own actions accordingly (Brownell, 2011; Meyer et al., 2010). In the example, the children monitor how the other grasps a block, predict where the other is going to place it, and adapt their placement of a block to when and where the block of the peer was placed, or hold the tower to prevent it from collapsing when the other child places the block.

During emergent coordination or entrainment, agents' rhythmic activity becomes coupled (Bernieri & Rosenthal, 1991; Schmidt & Richardson, 2008), as one can observe when the clapping of an audience becomes increasingly patterned over time (Néda et al., 2000). Characteristic of entrainment is that people often coordinate their rhythmic behaviors in one of two ways. Most frequent is in-phase coordination, whereby they move at the same time in the same direction, such as during walking in step when people lift and place their feet at the same time. Also frequent is anti-phase coordination, whereby they move at the same time in opposite directions, such as when walking hand in hand, resulting in one lifting her left foot while the other places her left foot (and lifting the right foot). People do not coordinate either in-phase or anti-phase, but approach both modes frequently during one interaction (Richardson, Marsh, Isenhower, Goodman, & Schmidt, 2007). These periods of in-phase and anti-phase coordination are interspersed with periods of uncoordinated behavior (Richardson et al., 2007; Richardson, Marsh, & Schmidt, 2005; Schmidt & O'Brien, 1997; van Ulzen, Lamoth, Daffertshofer, Semin, & Beek, 2008). Entrainment even can be coordination of different rhythms, such as a rhythm of two hits against a rhythm of three, or three against four (van Ulzen et al., 2008; Washburn, Coey, Romero, & Richardson, 2014). As the coupling of behavior occurs independently of joint plans or common knowledge (Knoblich et al., 2011) and often emerges and disappears without individuals being aware of it (Washburn et al., 2014), the term spontaneous interpersonal coordination is used throughout this thesis interchangeable with entrainment. Others prefer the term synchronization (cf. Feldman, 2007; Paxton & Dale, 2013b; Repp & Su, 2013; Schmidt, Morr, Fitzpatrick, & Richardson, 2012), as behaviors occurs at roughly or exactly the same time (Bernieri & Rosenthal, 1991; Lakin, 2012). In this thesis the term synchronization is reserved for coordination with an external event such as a metronome.

The role of intentionality is important in distinguishing cooperation from entrainment. Whereas entrainment occurs spontaneously, cooperation is an intentional attempt to participate in a joint activity (Louwerse, Dale, Bard, & Jeuniaux, 2012). However, this theoretically relevant difference cannot be made that clearly empirically. Namely, in cooperation studies in children, it cannot be determined whether the actions of both children are intentionally produced to reach the shared goal (Brownell, 2011). Moreover, as spontaneous coordination is difficult to study experimentally, many studies chose to instruct the participants to coordinate their behaviors (e.g., Kleinspehn-Ammerlahn et al., 2011; Skewes, Skewes, Michael, & Konvalinka, 2015; Vesper, van der Wel, Knoblich, & Sebanz, 2011). This instruction directs participants' attention to their rhythmic performance, which likely affects their intention, resulting in findings that are not representative of spontaneous coordination as it occurs outside the lab. When instructed and uninstructed entrainment is compared experimentally, uninstructed entrainment is weaker. Whereas instructed coordination is characterized by the achievement of in-phase or anti-phase coordination, spontaneous coordination also leads to other rhythmic couplings as well as to periods of uncoordinated behavior (Richardson et al., 2007; van Ulzen et al., 2008).

Development of cooperation

By 1 year of age, children mainly interact with peers around toys, but are not yet aware of their peers as potential cooperation partners, do not work towards a common goal, and therefore are not able to cooperate with a peer (Brownell, 1990, 2011; Steinwender, Warneken, & Tomasello, 2010). The predominant pattern of 1-year-olds is to try to achieve a goal independently (Brownell et al., 2006) or work for one's own goal rather than the joint goal (Brownell, 2011). But at age 3 children are cooperative (Brownell et al., 2006): They time their actions in accordance with their partner's actions and in relation to the goal, perform the right action in order to reach the common goal with the partner, and position themselves appropriately in relation to one another and the task, thus coordinating with respect to time, form (Bernieri & Rosenthal, 1991) and space (Brownell, 2011). What does children's development of uncooperative 1-year-olds to cooperative 3-year-olds looks like?

First, in order to cooperate, children have to position themselves appropriately in relation to one another and the task (Brownell, 2011). Most tasks, such as moving a large object together, require children to act at different locations. In order to move a table, it only makes sense to lift the table when both persons are at opposite ends. Before the age of 2, children seem to have difficulty with this location aspect. In a study in which one child had to pull a spring-loaded handle to let another child retrieve a toy that was blocked for the first child by a barrier, 12- and 18-month-olds failed to take the location of the partner into account, as they often did not act when the partner was near the toy or acted when the partner was too far away to retrieve the toy (Brownell & Carriger, 1990). In contrast, 24- and 30-month-olds were successful as they positioned themselves at the one location of the apparatus when the partner moved to the other. These findings were confirmed in another study by Brownell (2006) in which both children had to pull a handle at different locations in order to make an animal toy play a song. In this study, 19-month-olds pulled the handle half of the time when the peer was not in proximity of the other handle, while 27-month-olds were nearly twice as likely to pull their own handle when the peer was within reach of the other handle. Thus, 1-year-olds did not coordinate their actions with respect to space, but by age 2 children positioned themselves correctly in relation to each other and the task.

A notable difference between these two studies was the actions children needed to perform. In the first study, one child had to pull a handle whereas the other child needed to perform a different action. In the second study, both children needed to perform the same behavior and therefore could act in parallel. As children imitate peers' behavior during their second year (Eckerman et al., 1989), parallel acting might be easier than choosing a complementary response. Indeed, 75 percent of the 19-month-olds were successful at least once in coordination of parallel roles, as they pulled the handle together (Brownell et al., 2006). Only during the third year of life do children show coordination in cooperation tasks with complementary roles (Ashley & Tomasello, 1998; Steinwender et al., 2010) and start to switch roles (Brownell & Carriger, 1990; Steinwender et al., 2010).

To be successful at cooperation, children not only need to be located at the right positions and perform the correct behavior, they also need to time their actions well. In the previously mentioned task in which children needed to pull a handle in order to let a peer retrieve a toy, children below the age of 2 did not coordinate the timing of their behaviors (Brownell & Carriger, 1990). These children did not pause their pulling at the spring-loaded handle so that their peer could get the object. Brownell (2006) also used a task in which two handles had to be pulled sequentially: a music song did not start playing when both children pulled the handles at the same time, but only when they pulled the handles sequentially. This condition was much harder for all toddlers than the parallel handle-pulling version. When precise timing is needed for successful cooperation, even older children show difficulties. In a marble rolling game where children needed to put a finger in a hole at the right time to prevent the marble from falling, 5.5-year-olds performed worse than when the children had to act sequentially by opening a door to let the marble pass (Fletcher, Warneken, & Tomasello, 2012).

In summary, children's coordination develops rapidly with respect to timing, form, and location. Infants of 18 months of age are found to only incidentally coordinate their actions with a peer during simple games (Brownell, 1990; Brownell et al., 2006). Around age 2 children's coordinated acts rapidly improve, as they begin to take into account the position of their partner, extend their coordination skills from acting in parallel to complementary actions, and become better at waiting for their partner and adjusting the timing of their actions to those of a peer. This makes them skillful cooperative partners at age 3 although they continue to improve their timing after this age (e.g., Fletcher et al., 2012).

Development of entrainment

Whereas there is a large body of literature on interpersonal coordination in adults (see for reviews Repp, 2005; Repp & Su, 2013) entrainment studies with children are scarce. In the existing studies, mainly synchronization with an external rhythm or entrainment with an adult is studied. In these studies neither 2.5-year-old children (Provasi & Bobin-Bègue, 2003) nor 3-year-olds (Kirschner & Ilari, 2014) could synchronize their actions accurately to an auditory event. However, 2.5-year-olds were able to adjust their drumming tempo to an external beat that was close to their spontaneous motor tempo, and 3.5- and 4.5-year-olds could also adjust their tempo to a slower rhythm (Kirschner & Tomasello, 2009). When entraining with an adult rather than a drumming machine, even 2.5-year-olds were able to slow down their drumming when the adult drummed in a slower tempo (Kirschner & Tomasello, 2009). These studies indicate that although young children show tempo adjustments to an external beat, they do not reach an adult-like level of in-phase or anti-phase coordination.

Besides these synchronization studies with an external rhythm and entrainment studies with an adult, only Kleinspehn (2011) studied entrainment with a peer. She showed that when children in same- and mixed-aged dyads were instructed to coordinate their drumming, 5- and 12-year-olds were less accurate in coordinating their actions to a peer than to an older person. This suggests that interpersonal coordination between peers is more difficult than with an adult or an external beat. However, no studies have focused on peer coordination in young children, leaving the development of entrainment with peers unknown. Moreover, children were always instructed to coordinate. This probably made the coordination more intentional, resulting in more in-phase and anti-phase coordination as compared with other rhythmic couplings and periods of uncoordinated behavior (Richardson et al., 2007; van Ulzen et al., 2008). Thus, until now it is unclear how spontaneous interpersonal coordination develops. Therefore in this thesis we used, besides an instructed cooperation task, an entrainment task without instruction for coordination to resemble children's spontaneous coordination situations during social interaction.

SOCIAL EFFECTS OF PEER INTERACTION

Let us go back to the example of the musicians from the beginning. Imagine that the second violinist played his own part without adapting his play to the others. Would the other musicians be keen to form an ensemble with him on a next occasion? This may be less likely than if he adjusted his play perfectly to the others. And does the viola player picking up someone else's fallen music influence the other's eagerness to drink a beer with him afterwards? It could be. Hence, high interaction quality and interpersonal coordination may have positive social effects among interaction partners such as increased rapport, liking, or feeling to be a "team."

With respect to interaction quality, several studies have shown a relation with preschoolers' preference by their peers (e.g., Johnson, Ironsmith, Snow, & Poteat, 2000; Nelson, Robinson, Hart, Albano, & Marshall, 2010; Santos, Peceguina, Daniel, Shin, & Vaughn, 2013; Sette, Spinrad, & Baumgartner, 2013; Vaughn, Vollenweider, Bost, & Azria-Evans, 2003; Walker, 2009; Wilson, 2006). Children who display high levels of affiliative and low levels of antagonistic behaviors are better liked by their peers as compared with children who show lower frequencies of affiliative behaviors and higher frequencies of antagonistic behaviors. Studying whether children's interactive behavior in early childhood is predictive for their later peer relations is important, as peer rejection has far-reaching consequences for children's further social functioning in childhood (Berdan, Keane, & Calkins, 2008; Ladd, 2006; Ladd & Troop-Gordon, 2003; Morris et al., 2013; Wilson, Petaja, & Mancil, 2011), adolescence and adulthood (Bagwell, Newcomb, & Bukowski, 1998). To our knowledge, only two studies examined the predictive relation between toddlers' interaction quality and their peer preference in early childhood. Keane and Calkins (2004) followed children from 2 to 5 years of age, but did not find indications of a predictive relation. Friedlmeier (2009) yielded inconsistent results: a positive relation between toddlers' interaction quality and their later peer preference was found for a playgroup of six children who were 10 to 22 months old during the first assessment with a social evaluation 20 months later, but not for a playgroup of seven 30- to 42-month-olds with a social evaluation 12 months later. In sum, several studies have shown that preschool children's interaction quality is related to their social evaluation, but whether peer preference can be predicted from toddlerhood interactive behaviors still has to be established.

Also interpersonal coordination is expected to have social effects from early on, as adjusting flexibly to different social situations is seen as more socially skilled (Martin & Rubin, 1995). Social effects of interpersonal coordination have been studied widely in adults but there are only a few studies with children. In adults, interpersonal coordination has been demonstrated consistently to foster liking, feelings of connectedness, feelings of similarity, and affiliation with partners (e.g., Cacioppo et al., 2014; Hove & Risen, 2009; Lakens & Stel, 2011; Launay, Dean, & Bailes, 2014; Marsh, Richardson, & Schmidt, 2009; Miles, Nind, & Macrae, 2009). For example, during a joint plank-lifting task, adults who coordinated their actions better felt more positive towards each other (Marsh et al., 2009).

The positive consequences of coordination are also found in entrainment situations where there is no explicit goal to coordinate. For example, when adults' tapping became entrained with the tapping of an experimenter, their level of coordination predicted subsequent ratings of affiliation (Hove & Risen, 2009). This effect is unique to coordination with another person rather than a general preference for any experience of coordination, such as tapping in synchrony with a metronome (Hove & Risen, 2009). Moreover, the belief that one coordinates with a person instead of a computer, is already enough to foster liking (Launay et al., 2014). This social effect is not only experienced by the interaction partner, but also by others who observe the interaction (Lakens & Stel, 2011; Miles et al., 2009). Thus, interpersonal coordination, both during cooperation and entrainment, seems to have consequences for social evaluation among adults.

Several studies have shown that also children behave more prosocially after the experience of interpersonal coordination, both in cooperation and entrainment tasks. Kirschner and Tomasello (2010) found the first support for a relation of interpersonal coordination with prosocial behavior, as children showed more helping and communicative utterances after experiencing entrainment during music making than matched controls. Cirelli, Einarson, and Trainor (2014) found comparable results already in 14-month-old toddlers. In their study, the toddlers were bounced either in the same or a different rhythm as the movements of the experimenter. When the experimenter afterwards dropped objects 'accidently', those toddlers who had experienced coordinated bouncing were more likely to help. These effects were the same for in-phase coordination, anti-phase coordination, and coordination of an unevenly spaced rhythm, indicating that children's helping is based on the contingency of interpersonal coordination rather than on movement symmetry or ease of movement prediction (Cirelli et al., 2014).

Comparable results are found for cooperation. For example, 3.5-year-olds supported their cooperation partners by helping and waiting for them (Hamann, Warneken, & Tomasello, 2012). Moreover, 2- or 3-year-old children shared the rewards of a collaborative action with their cooperation partner (Hamann, Warneken, Greenberg, & Tomasello, 2011). These studies show that children behave prosocially towards people who coordinate their actions with them.

There are indications that children also like partners better who coordinate successfully and prefer him or her over others who coordinate less well interpersonally. School-age children rated a play partner more positively when their actions during joint drumming were well-coordinated (Kleinspehn, 2008). Moreover, 5-year-olds preferred a hand puppet with which they previously had coordinated their actions during a cooperative problem-solving task over another hand puppet (Plötner, Over, Carpenter, & Tomasello, 2015). Even by the age of 12 months, infants preferred a teddy bear that rocked in a chair to the same rhythm as them over a bear that was rocked to a different rhythm (Tunçgenç, Cohen, & Fawcett, 2015). This suggests that action coordination also has an impact on social evaluation in early childhood. If interpersonal coordination skills in early childhood have social effects, what does that imply for children's social development? Hypothetically, such a social effect of interpersonal coordination may extend to children's preference among their peers, such as their classmates at school, with children who coordinate their actions during peer interactions well being better liked by their peers than children who coordinate less well.

OUTLINE OF THE THESIS

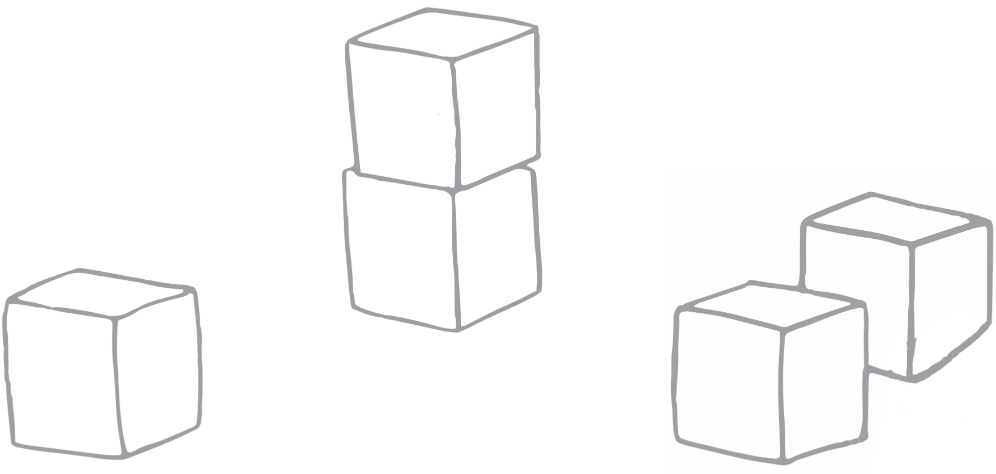
The aim of this thesis was to study the earliest building blocks of peer interaction. Mapping out the time course of interpersonal coordination abilities in young children, in terms of entrainment and cooperation and the interplay with interaction quality, is central to our understanding of children's social relations. To address these different aspects, a cross-sectional sample of 2-, 3- and 4-year-old children was studied to investigate the development of interpersonal coordination during peer interaction in a cooperation and entrainment task. The 180 2-year-olds were also followed longitudinally until the age of 4 to study the relation between their early peer interactions and later peer relations.

The **first research question** of this thesis was: How does children's interpersonal coordination develop? In **Chapter 1,** I examined the development of entrainment in a cross-sectional study on spontaneous drumming. **Chapter 2** focused on the development of cooperation in this cross-sectional sample.

The **second research question** was: What makes children perform better or worse in their interaction with a peer? **Chapter 2** also addressed this question as I examined whether differences in individual characteristics and experiences with peers were related to differences in their peer interaction. In this study I tested the effect of interaction quality on cooperation, and examined the role of temperament, social competence, gender, child care attendance and the presence of siblings in the three different age groups of the cross-sectional sample. In **Chapter 3**, I examined the neurocognitive processes that might underlie interindividual differences in interpersonal coordination in a neuroimaging study.

The **third research question** was: Is children's interaction behavior in toddlerhood predictive for their later social evaluation by peers? **Chapter 4** describes a methodological sociometric pre-study in a preschool sample, in which I developed a computerized method and compared it to offline ratings. In **Chapter 5** I examined in a longitudinal study whether interpersonal coordination and interaction quality in toddlerhood are predictors of peer preference at school.

In the **general discussion** I revisit the three main research questions, discuss possible underlying mechanisms of interpersonal coordination, and elaborate on the implications of the findings for further research and professionals working with young children.



Development of Interpersonal Coordination Between Peers During a Drumming Task

1

H. M. Endedijk
V. C. O. Ramenzoni
R. F. A. Cox
A. H. N. Cillessen
H. Bekkering
S. Hunnius

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ABSTRACT

During social interaction, the behavior of interacting partners becomes coordinated. Although interpersonal coordination is well-studied in adults, relatively little is known about its development. In this project we explored how 2-, 3-, and 4-year-old children spontaneously coordinated their drumming with a peer. Results showed that all children adapted their drumming to their partner's drumming by starting and stopping their drumming in a coordinated fashion, but only 4-year-olds adapted the rhythmic structure of their drumming to their partner's drumming. In all age groups, children showed similarly stable drumming. Typically, it was 1 of the 2 children who initiated drumming throughout the session. The results of this study offer new insights into the development of interpersonal coordination abilities in early childhood.

INTRODUCTION

Social interaction often requires that we coordinate our actions with those of others. Interpersonal coordination has been found when two people carry out motor acts during social interaction. This can be all kinds of behaviors such as walking (van Ulzen et al., 2008), finger movements (Oullier, de Guzman, Jantzen, Lagarde, & Scott Kelso, 2008), and chair rocking (Demos, Chaffin, Begosh, Daniels, & Marsh, 2012; Richardson et al., 2007). Although the literature on interpersonal coordination in adults is extensive, much less is known about the development of interpersonal coordination in early childhood. Most studies that explore the development of coordination have focused on how children coordinate with nonhuman external stimuli (cf. Kirschner & Tomasello, 2010; McAuley, Jones, Holub, Johnston, & Miller, 2006; Provasi & Bobin-Bègue, 2003; Zentner & Eerola, 2010). In the instances that coordination during social interaction was studied in children, mainly interactions with adults were examined (cf. Kirschner & Tomasello, 2009; Meyer et al., 2010). Coordination with peers has received, by comparison, very little attention. Mapping the time course of interpersonal coordination between peers is important to our understanding of early social development, because interpersonal coordination is closely related to social aspects such as cooperation and helping in young children (Cirelli et al., 2014; Kirschner & Tomasello, 2010; Kleinspehn, 2008). Moreover, this study is among the first to investigate interpersonal coordination in children younger than 4 years of age. We were especially interested in uninstructed coordination, as most interpersonal coordination in daily life is spontaneous. Therefore, the aim of this project was to explore 2-, 3-, and 4-year-olds' spontaneous coordination with a peer.

Tempo Stability

Tempo stability is suggested to be a prerequisite for interpersonal coordination (Lakin, 2012), as performing a stable tempo (i.e., evenly spaced rhythm) at different tempos is needed for adapting your behavior to other people's behavior. There are notable differences in children's tempo when asked to perform a stable tempo compared with that exhibited by adults in similar tasks. Children's spontaneously-produced tempo is faster than that of adults (Drake, Jones, & Baruch, 2000; McAuley et al., 2006), with intertap-intervals (ITIs) varying between 300 ms and 400 ms for 4-year-olds (Drake et al., 2000; Fitzpatrick, Schmidt, & Lockman, 1996; McAuley et al., 2006). The preferred tempo remains the same until the age of 7 (Drake et al., 2000; Fitzpatrick et al., 1996; McAuley et al., 2006) and slows down to ITIs around

600 ms in adulthood (Drake et al., 2000; McAuley et al., 2006). There is no information available about a preferred spontaneous tempo for children below the age of 4 although there is some evidence that children as young as 2.5 years show a stable tempo over short periods of time (Provasi & Bobin-Bègue, 2003).

The range of stable tempos increases with age. When children are asked to tap as fast as possible or as slowly as possible, the range in tempo younger children produce is smaller (it is of 262–731ms, 4–5 years of age) than the range older children (221–1,728ms, 6–7 years of age) and adults (169–2,532ms) show (Drake et al., 2000; McAuley et al., 2006). As they get older, children can produce a larger range of stable tempos because they can sustain different tempos without breaking performance. These findings suggest that stability develops in a way that makes it possible to generate and *maintain* stable tempo over time at different tempos, which is important for coordinating one's behavior with others.

Synchronization

Synchronization is the coordination of simultaneous rhythmic activity in time (Bernieri & Rosenthal, 1991). We use the term synchronization to refer to coordination of rhythmic movement with an external event (cf. Repp & Su, 2013). The development of synchronization with external events has usually been studied using tapping or drumming with metronome sounds and less frequently using music. Typically, synchronization has been measured as the temporal distance between the hit produced and the external event (Repp, 2005; Repp & Su, 2013). To date, most synchronization studies included only children of 4 years and older (cf. Clizbe & Getchell, 2010; de Boer, 2012; Drake et al., 2000; Getchell, 2007). From these studies, it appears that older children are better at synchronizing (Clizbe & Getchell, 2010; de Boer, 2012; Drake et al., 2000; Provasi & Bobin-Bègue, 2003), that they are less variable in their synchronization than younger children (Getchell, 2007; Provasi & Bobin-Bègue, 2003; Volman & Geuze, 2000) and that the range of frequencies they can synchronize with increases with age (Drake et al., 2000; Fitzpatrick et al., 1996; McAuley et al., 2006). Only two studies examined synchronization in children younger than 4 years. These studies found that neither 2.5-year-old children (Provasi & Bobin-Bègue, 2003) nor 3-year-olds (Kirschner & Ilari, 2014) could synchronize their actions to an auditory event.

Instead of examining synchronization at the level of tap or drum hits, by studying the timing of each produced hit to the external event, young children's coordination can also be described in terms of tempo flexibility. For example, Kirschner and Tomasello (2009) measured the ability of 2.5-, 3.5-, and 4.5-year-old children to adjust their tempo to an external beat around (ITIs of 400 ms) and below (ITIs of 600 ms) their spontaneous tempo. All age groups were able to coordinate their behavior to the external beat close to their preferred motor tempo, but only the two older age groups were able to adjust their tempo to the slower beat (Kirschner & Tomasello, 2009). In younger children (5 to 24 months), Zentner and Eerola (2010) found indications of spontaneous tempo flexibility, as children moved their arms and legs faster when listening to fast music. These findings highlight that young children are able to adjust their tempo to external events, and that coordination becomes better and more stable as children's ability to perform a broader range of tempos increases.

Interpersonal Coordination

Compared with coordination with external rhythmic events, coordination during social interaction can be easier for a child as they frequently practice this during daily social interactions. The study by Kirschner and Tomasello (2009) indeed showed that although 2.5-year-olds were not able to produce tempo adjustments to tempos below their spontaneous tempo with the drumming machine, they could do so when drumming together with an adult. However, recent work by Kirschner and Ilari (2014) showed that 3-year-old children were not able to coordinate their drumming actions after the adult changed the drumming tempo. These studies indicate that although young children show tempo adjustments to the adult tempo, they do not reach a level of coordination in which the timing of their hits is coordinated with the hits of the adult in the way that they hit the drum at the same time.

Moreover, Meyer et al. (2010) found that it is not until the age of 3 that children can acquire a comparable level of coordination interpersonally (i.e., when acting jointly with an adult) as intrapersonally (i.e., in the rhythmic structure of their own bimanual responses). In this study, 2.5- and 3-year-olds were instructed to play a sequential button-pressing game that could be played jointly or individually. Both age groups performed at the same level when acting individually. Of interest to the authors, while 3-year-old children timed their button presses equally well when they did the task alone or jointly with the adult, 2.5-year-olds were more variable in their timing in the joint condition as compared with the individual condition. Thus, although it seems easier for children to coordinate with an adult than with an external event, it is not until the age of 3 that they show comparable levels of intra- and interpersonal coordination and are able to adjust to different tempos with an adult.

While studies on child–adult coordination have provided intriguing findings on the development of coordination, critically, child–adult interactions are asymmetrical. This has at least two implications for how coordination unfolds: first, the adult's actions are more proficient and predictable than the child's and, second, adults have fully developed coordination abilities that allow them to accommodate for the instability in the child's actions which results in more coordination from adult to child. For instance, the 2.5-year-olds' difficulties with adapting their actions to those of a partner in Meyer et al.'s study (2010) might become even more salient if they had coordinated with a peer, as children are more variable and therefore more unpredictable than an adult partner. Indeed, when children in same- and mixed-aged dyads were instructed to coordinate their drumming, 5- and 12-year-olds were less accurate in coordinating their actions to peers than to an older person (Kleinspehn-Ammerlahn et al., 2011). This finding suggests that interpersonal coordination between peers is more difficult than coordination with an adult or external beat. However, because no studies have focused on peer coordination in young children, it is unclear to date how interpersonal coordination with peers develops and whether young children are indeed less predictable drumming partners as indicated by low tempo stability.

Current Study

To investigate interpersonal coordination development in young children, we studied spontaneous drumming in 2-, 3-, and 4-year-olds with a same-gender peer. Our goal was to comprehensively describe how drumming together with a peer changes over age both in terms of the development of tempo stability and interpersonal coordination.

We studied drumming performance at the level of individual drum hits and at the level of drumming patterns. For the first, we used the methodology of previous studies on synchrony and interpersonal coordination (ITIs and cross-correlations; Repp, 2005) by measuring the elapsed time between the hits produced by each child during the entire session. We investigated children's tempo stability by measuring their variability in ITIs (*SD* ITIs) by measuring how stable each individual hit produced by the children related temporally to the preceding and subsequent hits in their own drumming. Additionally, we measured children's interpersonal coordination by measuring maximum cross-correlations. Maximum cross-correlations indicate how the hits produced by a child related temporally the best to their partner's drumming. In line with other studies on coordination with an external event or adult (e.g., Clizbe & Getchell, 2010; Meyer et al., 2010), we expected older children to be better at coordinating their drumming with a peer than younger children.

Second, we studied the drumming patterns children produced during the session and the association with their partner's drumming patterns. In our study it became evident that young children tended to produce frequent long pauses in their rhythmic behaviors, which resulted in a pattern of drumming short bouts of hits separated by long periods with no hits. Therefore, within drumming bouts, we again studied the stability of children's drumming tempos, which is not affected by long pauses.

A rhythmic performance that exhibits patterns with long pauses has important consequences for interpersonal coordination: if interpersonal coordination were to emerge between partners, it would likely occur in the overlap between the drumming bouts of the partners. Consequently, to study peer-to-peer coordination we examined whether children converged more into overlapping drumming bouts as they got older. Moreover, we examined whether the overlapping drumming bouts were mutually coordinated by both children as is common in adults (Konvalinka, Vuust, Roepstorff, & Frith, 2010). Specifically, we were interested in whether both partners initiated overlapping drumming bouts or whether the drumming showed a leader–follower structure.

METHOD

Participants

The final sample consisted of 100 2-year-olds (50 dyads, *M* = 28.0 months, *SD* = .3), 60 3-year-olds (30 dyads, *M* = 40.2 months, *SD* = .3), and 66 4-year-olds (33 dyads, *M* = 55.3 months, *SD* = 4.1). Members of each dyad were of the same gender, and 55.3% of the dyads were male. There was no significant difference in the ratio of female and male dyads between age groups, $\chi^2(2, 113) = 1.53$, $p = .47$. The 2- and 3-year-old children were selected based on their age from a database of families who responded to an invitation letter sent to all families with infants in the Nijmegen area (a midsize city in the Netherlands with 165,000 inhabitants). All children were healthy and displayed no indications of atypical development. The 4-year-olds were recruited from a random selection of elementary schools in Nijmegen, of which two were willing to participate with their preschool classes. All parents were informed about the purpose of the study and signed a consent form before participation. The local ethical committee has approved this research.

The 2- and 3-year-old children were invited to the lab and randomly paired with an unfamiliar peer. The 4-year-olds were tested at their school and randomly paired with a peer from another classroom. Some children had seen their dyad partner before, but there were only two dyads that had actually played together previously. All participants spoke Dutch and came from mixed socioeconomic backgrounds. Three 2-year-olds and two 3-year-olds did not show up for their appointment, and therefore their dyad was excluded from the study. Moreover, all dyads in which one child or both children did not engage in the task at all were excluded from the final sample. This resulted in the exclusion of 39 of the 89 2-year-old dyads that had originally been recruited. For the 3-year-olds, 43 dyads had been recruited of which 13 had to be excluded, and the same was the case for 2 of the 35 recruited 4-year-old dyads. This resulted in the final sample of 50, 30 and 33 dyads of 2-, 3-, and 4-year-olds, respectively.

Materials

The equipment for the dyadic drumming task consisted of two 10-inch drums of a Hayman kid drum set (Hayman, London) and two plastic sticks (see Figure 1.1). The drums were placed on a stand, which could be adapted to the height of the children so that they could comfortably drum in standing position. The drums were connected via piezo contact microphones placed on the drumheads to collect MIDI data via an Alesis D4 drum module (Alesis Innovations, Cumberland, RI). Performances were recorded with Logic Express (Apple Inc, Cupertino, CA).

Procedure

The session started with 5 to 30 minutes of free play during which the children could familiarize with the two experimenters and each other. The duration of free play differed across age groups, as older children needed less time for this phase. This introductory phase was followed by a peer cooperation task based on the double tube task by Warneken et al. (2006) that took 5 minutes. For a detailed description of the task as well as a report on children's performance on this task, please see Endedijk, Cillessen, Cox, Bekkering and Hunnius (2015 (Chapter 2)). Following the cooperation task, the dyadic drumming task was presented. Children did not receive any instructions pertaining to drumming together or coordinating their drumming with their dyad partner. Parents, who were present during the sessions of 2- and 3-year-olds, were instructed to minimize their interactions with the child and, if the child was clinging to the parent, to respond in ways to stimulate play without helping

Figure 1.1. A 3-year-old dyad performing the drumming task.

with the task. If a child did not start drumming, one of the experimenters started drumming on a third drum to encourage him or her, but stopped the drumming as soon as the child started to drum. When a child stopped drumming, he or she was encouraged to continue drumming. The drumming sessions lasted for a maximum of 5 minutes and ended when both children spontaneously stopped drumming. During the sessions with 4-year-olds, parents were not present and there was only one experimenter, as they took place at school. At the end of the session, the 2- and 3-year-old children received a book or 10 Euros "for their piggy bank" as a thank you for participation. Teachers of the 4-year-olds were offered a picture book for the participation of their class. The entire testing session was videotaped from two visual angles using two video cameras.

Data Reduction and Analysis

The raw data from the drumming recordings were compared with the actual behavior of the children on the video recordings to establish start and end of each drumming session, to exclude sections during which the experimenter encouraged drumming by using the third drum, and to remove extra drum hits that occurred when a microphone accidentally registered an extremely loud hit as two hits or captured hits produced by the other child. All hits of the children that remained after the data cleaning were used in the first set of analysis (see Drum Hits in the Results section). To investigate changes in tempo stability between age groups, we calculated the variability in intertap-intervals (*SD* ITIs) by calculating the *SD* of the time elapsed between hits. Interpersonal coordination was measured in terms of the temporal similarities between the time series of ITIs (consecutive ITIs) obtained for each child, using maximum cross-correlation functions. To do so, the time series of ITIs of two partners were correlated across time to identify the highest association between the time series.

For the second set of analyses (see Drumming Bouts in the Results section), drumming bouts (i.e., a sequence of hits) were extracted from the cleaned drumming data using three rules. First, the first and last hit of a bout was defined as any hit for which the ITI between the hit and the previous hit, or next hit in case of the last hit of a bout, was bigger than 2.5 times the previous (or next) ITI. As a result, a bout was separated from another bout when there was a pause in the child's drumming or when a strong shift in drumming tempo occurred. Second, bouts had to contain at least three hits to prevent single hits from being selected as a bout. Third, a ratio was calculated between the number of hits within a bout and the total duration of the bout. Bouts with a ratio value smaller than 2.5 *SD*s below the mean ratio for all bouts in all children were removed. This was done to exclude bouts that did not consist of hits closely related in time to each other, but rather of single hits with comparably large ITIs. For the set of analyses at the level of bouts, again differences in tempo stability and interpersonal coordination were calculated between age groups. Tempo stability was calculated as the average *SD* of temporal distance between hits (*SD* ITIs) during bouts. Interpersonal coordination between bouts was studied by measuring the degree of overlap between bouts of two partners. To establish whether both partners coordinated mutually or showed a leader–follower structure in producing overlapping bouts, the initiation of these overlapping bouts by each partner was determined.

Age differences were tested using a one-way analysis of variance (ANOVA) with age as between-subjects factor and Bonferonni corrected post hoc tests. To test whether coordination was better than expected by chance, the observed time series of the ITIs of each child were randomly scrambled resulting in two new time series for each dyad (cf. Shockley, Santana, & Fowler, 2003). Interpersonal coordination was tested by ANOVA with age as a between-subjects factor and time series (observed vs. randomized) as a within-subjects factor.

RESULTS

Drum Hits

Tempo stability

Based on all ITIs during the entire drumming session including pauses, children of 2, 3, and 4 years showed differences in drumming tempo. ITIs decreased significantly with age, $F(2, 223) = 5.07$, $p = .007$, $\eta^2 = .04$, with Levene's test indicating unequal variances, $F(2, 223) = 9.41$, $p < .001$. Post-hoc analyses showed slower tempos and larger variances for 2-year-olds (M = 3.00 seconds, SD = 7.09) than for 4-year-olds (M = .51, SD = .15) and no differences between these age groups and the 3-year-olds (M = 1.78, SD = 2.88). Post-hoc age comparisons also yielded a significant difference of age 2 (M = 5.03, SD = 7.15) and age 3 (M = 4.02, SD = 6.36) versus age 4 on the variability in ITIs (SD ITIs: M = .77, SD = .59), with older children drumming in a more stable manner than younger children, $F(2, 223) = 11.08$, $p < .001$, $\eta^2 = .09$. Again Levene's test indicated unequal variances, $F(2, 223) = 19.21$, $p < .001$. These results suggest that as children grow older drumming becomes faster and more stable. The average ITIs and variability in ITIs are large in comparison with the tempos found in earlier studies for children (300 to 400 ms for 4-year-olds). These large ITIs and their high *SDs* for mainly the younger age groups, in combination with unequal variances suggest that younger children tend to drum in bouts with pauses in between. The average ITIs and *SDs* of ITIs are, therefore, no valid measure of young children's actual tempo and tempo stability.

Interpersonal coordination

Maximum cross-correlation coefficients obtained for the time series of ITIs of the partners in each dyad were tested for age differences and compared with the maximum cross-correlation coefficients for the randomized time series. An ANOVA with age as a between-subjects factor and the time series (observed vs. randomized) as a within-subjects factor yielded a main effect of age, $F(2, 110) = 6.68$, $p = .002$, $\eta^2 = .11$. Post-hoc tests indicated significant differences between the 2- and 4-year-old dyads, with 4-year-old dyads showing larger maximum cross-correlations (M = .71,

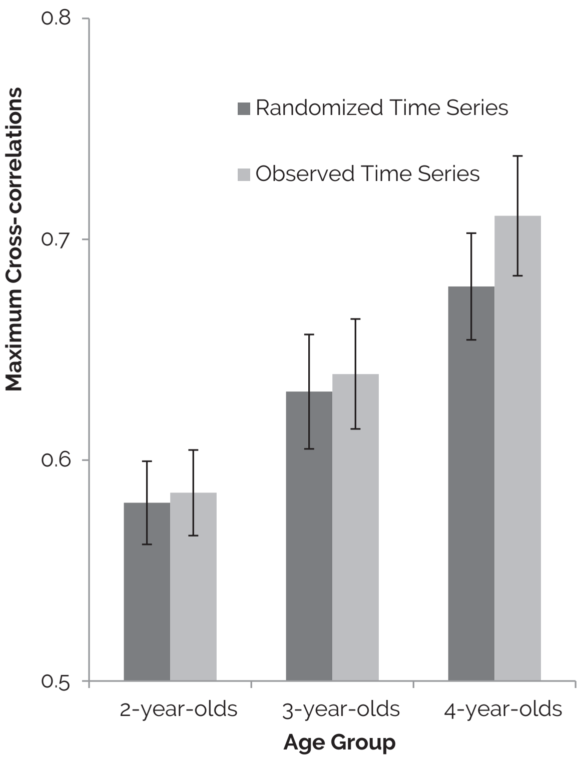


Figure 1.2. Maximum cross-correlations with *SE*s of randomized and observed time series for 2-, 3- and 4-year-olds.

SD = .16) than 2-year-old dyads (*M* = .58, *SD* = .14). The 3-year-old dyads (*M* = .64, *SD* = .14) were not significantly different from the other two age groups. There was a main effect of observed versus randomized time series, $F(1, 110) = 6.63$, $p = .01$, $\eta^2 = .06$, but no significant interaction effect with age, $F(2, 110) = 2.26$, $p = .11$, $\eta^2 = .04$ (see Figure 1.2). Although the interaction was not significant, the results in Figure 1.2 suggest that the difference between the time series was larger for 4-year-old dyads than for the two younger age groups. Therefore, we conducted paired sample *t*-tests for each age group separately comparing observed versus randomized time series. The *t*-tests yielded no significant effects of time series for the two younger age groups, $t(49) = .59$, $p = .56$, $\eta^2 = .01$ and $t(29) = .75$, $p = .46$, $\eta^2 = .02$, respectively, but a significant effect for the 4-year-old dyads, $t(32) = 2.69$, $p = .01$, $\eta^2 = .18$. These findings suggest that 4-year-olds coordinated their hits with each other.

Drumming Bouts

Tempo stability and interpersonal coordination were further examined based on the drumming bouts produced by each child. Figure 1.3 demonstrates an example drumming recording of a dyad per age group thereby illustrating that the children drummed in bouts. With respect to tempo stability, the tempo variability (*SD* ITIs) within bouts instead of within the entire time series (including pauses), may clarify whether age differences in interpersonal coordination could be because of age-related changes in drumming stability. Children who did not produce at least one bout were removed from this analysis (viz. seven 2-year-old and two 3-year-old children).

One-way ANOVAs with age as a between-subjects factor showed that older children produced bouts with a longer average duration, $F(2, 214) = 10.52$, $p < .001$, $\eta^2 = .09$, and more hits per bout, $F(2, 214) = 15.38$, $p < .001$, $\eta^2 = .13$ (see Table 1.1 for descriptive statistics). Post-hoc analyses indicated that 4-year-olds differed significantly on these measures from 2- and 3-year-olds, who did not differ from each other. Comparison of the percentage of time children produced bouts relative to their total drumming time (time elapsed between their first and last drumming hit) over age groups showed that older children spent more time drumming in bouts,

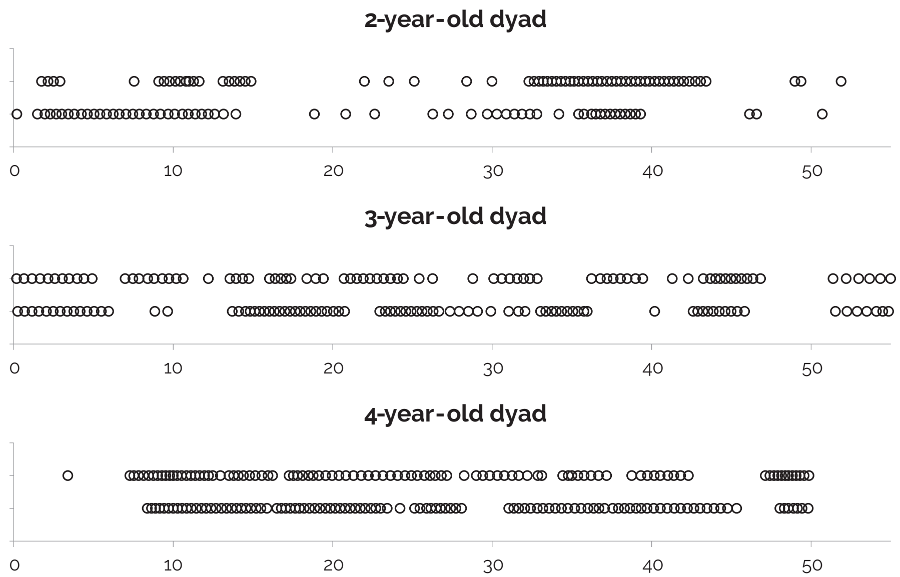


Figure 1.3. Example of the drumming recording of a dyad of 2-, 3-, and 4-year-old children that illustrates that they drum in bouts and produce longer sustained drumming over age.

Table 1.1. Bouts: Duration of Bouts, Number of Hits per Bout and Percentage of Time Spent Producing Bouts Relative to Total Drumming Time for 2-, 3- and 4-Year-Old Children

	Age group					
	Age 2		Age 3		Age 4	
	M	*SD*	*M*	*SD*	*M*	*SD*
Duration (s)	6.32	5.46	7.07	4.25	11.72	11.55
Hits (#)	15.48	12.11	17.76	9.94	33.14	33.32
Time spent producing bouts relative to total drumming time (%)	37.76	22.65	49.42	28.30	70.13	18.46

Note. s = seconds, # = number, % = percentage.

$F(2, 214) = 37.76$, $p < .001$, $\eta^2 = .26$. Post-hoc analyses revealed that all age groups differed significantly from each other. This indicated that the drumming patterns of younger children were characterized by shorter periods of drumming with more or longer pauses compared with older children.

Tempo stability

Average ITIs within bouts decreased significantly with age, $F(2, 214) = 3.97$, $p = .02$, $\eta^2 = .04$. Post-hoc analyses showed significantly faster tempos for 4-year-olds ($M = .41$, $SD = .12$) than for 2-year-olds ($M = .48$, $SD = .21$), whereas 3-year-olds ($M = .44$, $SD = .09$) did not differ from the other age groups. In contrast to tempo stability as calculated for the entire time series (including pauses), children did not differ in their tempo stability during bouts (*SD* ITIs averaged across bouts), $F(2, 214) = .30$, $p = .74$, $\eta^2 < .01$, with an average *SD* ITIs of .12 seconds ($SD = .08$). Thus, there was no indication of significant differences between age groups in tempo stability when drumming was considered in bouts.

Interpersonal coordination

To investigate how dyads coordinated their drumming at the level of the bouts we studied the overlap between their drumming bouts. Coordination can exist of the same behavior of both partners at the same time (i.e., both children produce a bout at the same time) or by a turn-taking structure in which the partners produce bouts after each other. Most bouts children produced overlapped with a bout by their partner (see Table 1.2 for descriptive statistics), $t(214) = 10.06$, $p < .001$, $\eta^2 = .32$, and the percentage of overlapping bouts increased with age, $F(2, 214) = 22.88$, $p < .001$, $\eta^2 = .18$. Post-hoc tests revealed significantly higher overlap for 4-year-olds than for

Table 1.2. Overlapping Bouts: Percentage of Overlapping Bouts, Duration of Overlapping Bouts, Number of Hits per Overlapping Bout, Percentage Leader, Percentage of Time Spent Producing Overlapping Bouts Relative to Time Spent Producing Bouts for 2-, 3- and 4-Year-Old Children

	Age group					
	Age 2		Age 3		Age 4	
	M	*SD*	*M*	*SD*	*M*	*SD*
Percentage	59.66	36.03	70.06	31.86	91.80	12.94
Duration (s)	4.03	3.50	4.80	2.99	7.70	9.42
Hits (#)	10.10	8.20	11.93	7.14	21.91	27.14
Leader (%)	72.85	17.58	71.40	18.48	70.96	18.21
Time spent producing overlapping bouts relative to time spent producing bouts (%)	53.64	26.77	64.63	28.01	82.28	16.34

Note. s = seconds, # = number, % = percentage.

2- and 3-year-olds. These results indicate that all age groups showed a coordinative pattern of drumming at the same time (at least partly overlapping in time) more often than turn-taking patterns. Moreover, 4-year-olds showed overlap more frequently than the two younger age groups.

After removing dyads without any overlapping bout (11 2-year-old and two 3-year-old dyads), a one-way ANOVAs revealed that overlapping bouts lasted longer in older dyads, $F(2, 97) = 3.53$, $p = .03$, $\eta^2 = .07$, and that older children produced more hits per overlapping bout, $F(2, 197) = 9.70$, $p < .001$, $\eta^2 = .09$ (see Table 1.2). Post-hoc tests indicated a significant difference between the 4-year-olds compared with 2- and 3-year-olds for the number of hits, and a difference between 2- and 4-year-olds but not compared with 3-year-olds for the duration of overlapping bouts. To test whether older children spent more time producing overlapping bouts, independently of the overall amount of drumming activity, time spent drumming in overlapping bouts was divided by the duration of bouts produced by each child. These proportions of time spent producing overlapping bouts were tested for age differences and compared with the same measures as calculated based on the randomized time series. An ANOVA with age as between-subjects factor and time series (observed vs. randomized) as within-subjects factor yielded a main effect of time series, $F(1, 183) = 210.58$, $p < .001$, $\eta^2 = .54$. Children showed significantly better coordination as measured by the time spent drumming in overlapping bouts than based on chance. There was also a main effect of age, $F(2, 183) = 19.54$, $p < .001$, $\eta^2 = .18$, but no interaction-effect between age and time-series, $F(2, 183) = 1.06$, $p = .35$, $\eta^2 = .01$. Post-hoc tests indicated significantly more overlapping drumming for 4-year-olds as compared with 2-, and 3-year-olds. In summary, children showed coordination at the level of the bouts, and older children showed more coordination, as they showed a higher degree of overlap in their drumming.

Interpersonal coordination between bouts can originate from peers mutually adapting to each other's drumming or from a leader–follower relationship. We examined these options by determining who initiated the overlapping drumming (i.e., the proportion of overlapping bouts started by each child). On average, 71% of the overlapping bouts were started by the same child (the leader) while the other child followed, with no difference between dyads of different age groups, $F(2, 97) = .11$, $p = .90$, $\eta^2 < .01$. This percentage of overlapping bouts initiated by the same child was significantly different from what would indicate mutual adaptation (i.e., 50% of the overlapping bouts initiated by each child), $t(97) = 15.76$, $p < .001$. This indicates that all age groups displayed drumming patterns with considerably-stable leader and follower roles, with no indication of age differences in these leader–follower roles.

DISCUSSION

In this study, we investigated spontaneous coordination of 2-, 3-, and 4-year-old children with a peer in a drumming task. We examined both tempo stability and interpersonal coordination at the level of hits and bouts. It is common in research on coordination to examine how the timing of each produced hit during the entire time series is related to the hit of another person or external device (see Repp & Su, 2013). Our results suggest that when the drumming behavior exhibited by children is not continuous but characterized by periods of closely related hits (i.e., bouts) and pauses, analyzing the entire time series is not as informative and could be potentially misleading. For instance, analyses over the entire time series showed that the older children's drumming was more stable than that of the younger children. However, when considering drumming in bouts, the age difference in tempo stability disappeared. Likely because they could maintain a stable drumming tempo for longer periods, 4-year-olds coordinated their hits. This was not the case for the younger children: 2- and 3-year-olds were not able to coordinate their hits better than chance. However, children spontaneously coordinated their drumming in bouts, as most of the time they produced a bout when their partner was doing the same. Moreover, the drumming of older children spontaneously overlapped to a higher degree than that of younger children. Drumming patterns were not mutually coordinated, but periods of overlapping drumming tended to be initiated by one of the children in the dyad, while the other child followed.

As hypothesized, older children were better at coordinating their behaviors with a peer than younger children at the level of the drum hits. Moreover, the maximum cross correlations only revealed evidence for coordination of the timing of hits for 4-year-old dyads. Younger children could maintain a stable drumming tempo for only a short time, which likely limited the possibilities to coordinate their hits. It is likely that, similar to adults (Roerdink, Bank, Peper, & Beek, 2011; Semjen, Vorberg, & Schulze, 1998), children require some time to coordinate interpersonally, in which case a longer sustained rhythm might help them to adapt their behavior to the drumming of the partner.

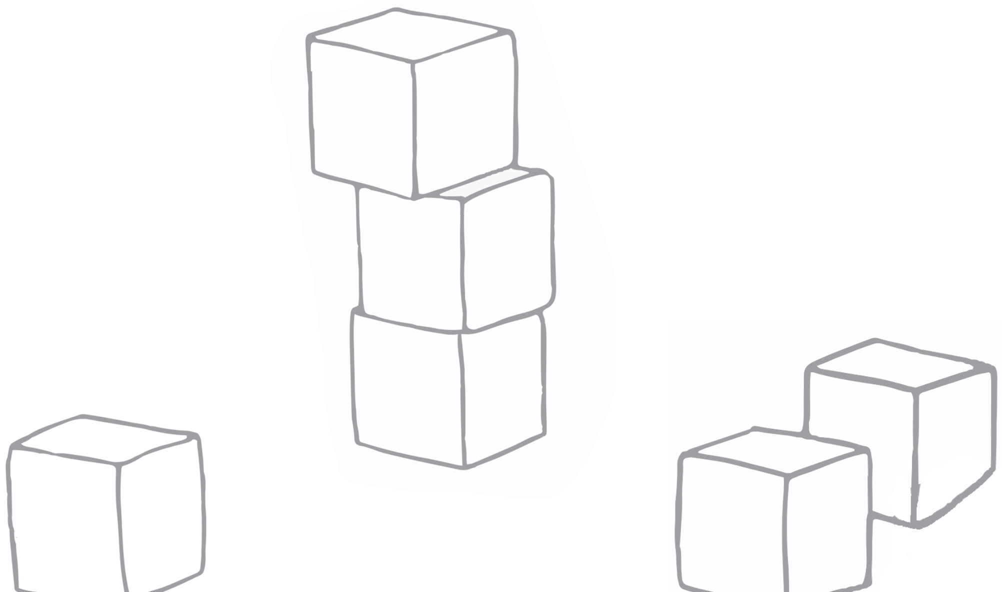
While 4-year-olds coordinated the timing of drum hits, children between 2- and 4 years of age showed indications of interpersonal coordination as indicated by the beginnings and endings of drumming bouts. Children showed more overlap in their bouts than would be expected by chance, and older children showed a higher degree of overlap than younger children even when controlled for the amount of drumming activity. This extends earlier findings that children become more successful at coordinating their behavior with external rhythms (cf. Clizbe & Getchell, 2010; de Boer, 2012; Drake et al., 2000; Provasi & Bobin-Bègue, 2003) and adults (Kirschner & Tomasello, 2009; Kleinspehn-Ammerlahn et al., 2011) as they get older. The present results suggest that young children also progressively become more proficient at coordinating their rhythmic behaviors to peers.

The improvement in interpersonal coordination with age cannot be explained by changes in the partners' tempo stability, as all age groups showed comparable stability in their drumming when the pauses between drumming bouts were not taken into account. In other words, it is not the case that 2-year-olds simply have a harder time coordinating with their peer because task demands change depending on the demands imposed by a more or less stable and predictable partner. This is in line with previous results by Getchell (2006) and Fitzpatrick et al. (1996), who found no differences in the stability of clapping and walking between 3 and 8 years. Our results suggest that changes in tempo stability might not significantly influence interpersonal coordination in early childhood. It is an open question whether such influences might arise in middle childhood, when significant gains in tempo stability have been documented (Fitzpatrick et al., 1996).

Our finding that all age groups showed comparable tempo stability but differences in their interpersonal coordination is, nevertheless, surprising, as producing stable tempos is assumed to be a prerequisite for coordination with a partner (Lakin, 2012). It also complements our understanding of social coordination processes in adults. In coordination tasks, people sometimes adjust the stability of their behavior to their partner. For example, they modify their speaking patterns or musical performance as to make themselves maximally predictable for a partner (Repp & Su, 2013; Vesper et al., 2011). On the one hand, sustained drumming for longer periods of time (as we found in older age groups) might have served a similar purpose. On the other hand, improved attunement has been demonstrated between children and parents by more variability and flexibility in language acquisition during the age of 1.5 and 2.5 years (Cox & van Dijk, 2013). This suggests that interpersonal coordination entails a delicate balance between the stability and the flexibility of behavior.

We also found that children's dyadic drumming showed a leader–follower pattern, in which one child initiated the overlapping drumming periods and the other child joined the initiator. Konvalinka et al. (2010) found that when adults were instructed to coordinate, they mutually adapted to each other. Although this seems at odds with our findings of leader–follower roles, directionality in initiations of overlapping drumming could be unrelated to mutual adaptation during periods of overlap. It is possible that in our sample, despite directionality in the initiation of drumming bouts, both children still mutually adapted their hits within these overlapping bouts to each other. The children in our study received no instruction that might have led to less focus on the partner's drumming and more on social and communicative aspects of the task. Such a relationship between interpersonal coordination and social factors in children is supported by earlier studies (Cirelli et al., 2014; Kirschner & Tomasello, 2010; Kleinspehn, 2008). In this respect, the combination of personality traits might be at the heart of why one child initiated and the other child followed in drumming. From the perspective of social development, this possible association certainly deserves more in-depth investigation in future studies.

In summary, the current study confirms previous findings on the development of interpersonal coordination in young children and extends them to encompass age-related changes in spontaneous coordination abilities with peers. We found that young children coordinated their drumming bouts. By age 4 children not only spontaneously coordinated when they drummed, but also how they drummed, by coordinating when they hit the drum to changes in their partners' drumming. These results are illustrative of how young children adapt their behavior in daily situations in which spontaneous coordination is often required, although the results cannot be generalized to situations in which they are instructed to coordinate. The findings of this study emphasize the importance of studying coordination at different time-scales by focusing not only on drum hits but also on drumming bouts. This provides a more comprehensive understanding of coordination especially in young children that have more difficulty with sustaining a rhythmic behavior. Moreover, our study contributes to a growing understanding of interpersonal coordination in early childhood (see Repp & Su, 2013) and it presents a new method for exploring the genesis of accommodation in social interactions. A longitudinal study in which children are followed in their interpersonal peer coordination could further clarify this time course, the individual developmental trajectories of interpersonal coordination, and the association with children's early social interactions with peers.



The Role of Child Characteristics and Peer Experiences in the Development of Peer Cooperation

H. M. Endedijk
A. H. N. Cillessen
R. F. A. Cox
H. Bekkering
S. Hunnius

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ABSTRACT

Cooperation with peers is challenging for young children, and there are large interindividual differences in the development of cooperation. The roles of child characteristics and peer experiences for peer interaction during free play have been studied extensively, but it is unclear which factors predict young children's successful cooperation at different points in development. In this study, 2-, 3-, and 4-year-old children were observed during a peer cooperation task. Both their interactive behavior and cooperation success were examined, and the association of these variables with child characteristics and peer experiences was explored. Results showed that successful peer cooperation increased with age. Moreover, early interindividual differences in peer cooperation were related to temperamental characteristics, and, among older children, the rate of cooperation was related to prior peer experience.

INTRODUCTION

Cooperation with peers is important in children's daily lives, as everyday actions such as building a block tower together require successful cooperation. Peer cooperation is conceptualized as coordinated interaction between peers to reach a common goal (Brownell et al., 2006). For instance, cooperation requires the ability to regulate one's own behavior (Brownell, 2011; Meyer et al., 2010) and to predict and monitor the other person's behavior (Meyer et al., 2011; Vesper et al., 2010). The ability to cooperate with peers has been observed only incidentally in 18- or 19-month-old infants, whereas 23- to 30-month-old children have been shown to cooperate more effectively and quickly (Brownell & Carriger, 1990; Brownell et al., 2006). Although there are large interindividual differences in when children begin to show signs of peer cooperation (Eckerman & Peterman, 2004), relatively little is known about the factors that influence cooperation in young children.

Despite a lack of studies on factors that influence cooperation, multiple aspects have been studied in relation to (not necessarily coordinated) peer interactions through observation of free play (e.g., Gevers Deynoot-Schaub, 2006; NICHD Early Child Care Research Network, 2008). These factors can be divided in two broad groups: child characteristics and peer experiences. Our main research question therefore addressed whether young children's cooperation capabilities are related to their individual characteristics and to their experiences with peers. We also examined how consistent such associations are across age. Insight on these issues will provide information about interindividual differences in cooperation across development and can inform ways to stimulate children's cooperation abilities.

Child Characteristics

Studies that examined child characteristics in relation to peer interaction during free play mainly focused on the role of gender and temperament (e.g., Hay, Caplan, & Nash, 2009). Also social competence is often related to peer interaction (e.g., Hawley, 2002; Webster-Stratton & Lindsay, 1999).

During free play, girls have been described to display more cooperative, mitigating, or positive behaviors, whereas boys tend to be more competitive and aggressive. This is found across development, during infancy (Gevers Deynoot-Schaub, 2006), toddlerhood (Lamb & Ahnert, 2006), and preschool years (Dodge et al., 2006; Holmes-Lonergan, 2003; Maccoby, 2002; NICHD Early Child Care Research Network, 2001).

Differences in temperament, such as children's activity level or their ability to regulate emotions, also influence early peer interaction (Hay et al., 2009). Although it seems commonly accepted that children with a difficult temperament face more problems in peer interaction than children who are easy-going (e.g., Gevers Deynoot-Schaub, 2006), the exact associations of the three main dimensions of temperament, negative affectivity, surgency, and effortful control with peer interaction have hardly been studied (see Rothbart & Bates, 2006). In school-age children, higher general activity (surgency) is related to lower levels of peer-rated prosocial behaviors (Sterry et al., 2010). Negative affectivity seems to play a role in the amount of peer interaction in which children engage, as Williams et al. (2007) found that infants with higher negative affectivity at 12–17 months showed more passive withdrawal from peer interaction 6 months later. Finally, a lack of effortful control may result in social problems, as effortful control allows children to shift attention from an immediate reward to the likely consequences of their behavior (Rothbart, Ahadi, & Hershey, 1994). Thus, it can be expected that less surgency and negative affectivity, and more effortful control are related to better interactions with peers in young children.

Social competence includes a broad range of competencies such as imitation and pretend play skills, empathy, emotional awareness, and prosocial behavior (Carter, Briggs-Cowan, Jones, & Little, 2003). A socially competent child is expected to be sensitive and empathic, engage in complex play, form friendships, and solve social problems (Howes, Matheson, & Hamilton, 1994). To our knowledge, there is only one study that related social competence in young children to their interaction behaviors with peers. Gevers-Deynoot-Schaub and Riksen-Walraven (2006) found that social competence in 23-month-olds, but not in 15-month-olds, was related to more positive initiatives and more frequent interactions with peers.

Peer Experiences

Children's experiences with siblings and other peers provide a unique context to explore and practice interaction skills (Lamb & Ahnert, 2006; McCoy, Brody, & Stoneman, 1994). Previous research that examined how experience with peers is related to interactions with peers has focused on the experiences young children gain within their families (e.g., with siblings) as well as outside their family homes (e.g., in child care settings).

Although one might expect a positive influence of peer experiences on the quality of peer interaction, findings on the effects of siblings have been inconsistent (Hay et al., 2009). For example, Downey and Condron (2004) concluded that preschool children growing up with at least one sibling indeed exhibited better interpersonal skills with peers than children without a sibling. However, Hay, Castle, Davies, Demetriou, and Simson (1999) found that toddlers with older siblings were less likely to share with peers than toddlers with younger siblings.

With respect to child care attendance, studies have reported both positive and negative associations of child care with the quality of peer interaction. On the one hand, associations have been found of child care attendance with increased complexity of social interactions, positive affect, and sociability (Loeb, Bridges, Bassok, Fuller, & Rumberger, 2007; NICHD Early Child Care Research Network, 2001, 2002b, 2008). On the other hand, negative correlates of child care attendance also have been reported, such as externalizing behavior problems, in toddlers (Loeb et al., 2007) as well as preschoolers (NICHD Early Child Care Research Network, 2002a). The intensity of child care attendance might play a role in this respect, as the association of child care with behavior problems was more pronounced for children who entered child care at an earlier age and for children who spent more hours per week in child care (Loeb et al., 2007).

Child Characteristics and Peer Experiences as Predictors of Cooperation

The above overview of the literature suggests a significant contribution of both child characteristics and peer experiences to the quality of peer interaction during free play. An important question is whether these factors are also related to the development of peer cooperation as an especially challenging form of peer interaction. When cooperating, interactions have to be coordinated to reach a common goal (Brownell et al., 2006). In order to examine the associations of children's characteristics and peer experiences with the quality of interactive behavior during cooperation and with cooperation success, we studied same-gender dyads of 2-, 3-, and 4-year-olds during a cooperation task. Children's social competence and temperament were assessed using parent reports. To examine children's experiences with peers, we noted whether they had siblings and attended child care. We expected that the quality of interactive behavior during a peer cooperation task would be positively related to cooperation success on the task. Moreover, we examined how child characteristics and peer experiences were related to the quality of interactive behavior and cooperation success. We expected an increase in cooperation success with age given increased competence in more difficult cooperation tasks during the third year of life. To examine developmental changes, we examined how child characteristics, peer experiences, and interactive behavior predicted increased cooperation competence across age.

METHOD

Participants

The final sample consisted of 126 two-year-old children (*M* = 27.97 months, *SD* = .32), 70 3-year-old children (*M* = 40.21, *SD* = .28), and 70 4-year-old children (*M* = 55.14, *SD* = 4.12). The 2-year-old group was larger, as those children were part of a longitudinal study on cooperation development. Of all children, 53% were boys. There was no age group difference in the ratio of girls to boys. The 2- and 3-year-old children were selected from a sample of families who were part of a database of parents in the Nijmegen area (a Dutch city with approximately 165,000 inhabitants) and who were willing to participate with their child in research. Two schools from the same area participated with classes of 4-year-olds.

The 2- and 3-year-old children were invited to the lab and randomly paired with an unfamiliar same-gender peer. The 4-year-old children were tested at their school outside the classroom, and randomly paired with a same-gender peer from another class. Some children had seen their dyad partner before, but only two dyads had actually played together previously. Most children were Dutch and came from mixed socioeconomic backgrounds. Parents were informed about the study and signed a consent form. Three 2-year-olds and two 3-year-olds did not show up for their appointment; therefore the other children of these dyads were excluded from the study. Furthermore, dyads were excluded if one child never got involved in the task, as the other child in these dyads did not have the possibility to cooperate successfully. This resulted in the exclusion of 26 two-year-old dyads and 8 three-year-old dyads. Questionnaires of 16 children were missing, but those children were kept in the sample, because the questionnaires of their dyad partners were available.

Peer Cooperation Task

The peer cooperation task was based on Warneken et al.'s (2006) double-tube task. The setup consisted of two 1-meter tubes mounted in parallel on a box with a 45-degree incline (see Figure 2.1). The two children were shown a Playmobil figure (Geobra Brandstätter GmbH & Co.KG, Zirndorf, Germany) in a swimsuit and a small swimming pool. They were instructed that the figure wanted to go through the sliding tube to the swimming pool. The tubes were too long for one child to simultaneously hold the swimming pool and insert the figure into the tube.

Figure 2.1. Children cooperating successfully on the peer cooperation task.

Two experimenters demonstrated the task twice in person to the 2- and 3-year-olds. The 4-year-olds received the instructions via a pre-recorded video. After the demonstration, the Playmobil figure and swimming pool were put on the floor so that both children were able to play with the materials. When children did not choose the same tube, they were reminded verbally (up to three times) that the figure wanted to go to the pool. Subsequently, children were only stimulated to play by saying that the figure wanted to slide again. If a child did not participate in the game during the first 2 minutes or five sliding trials of their partner, the experimenters performed the task together with both children twice. During these practice trials, one child was given the role of holding the swimming pool and the experimenter helped to hold the swimming pool below one of the tubes, whereas the other child was stimulated to insert the figure into one of the tubes. If thereafter a child still did not get involved, the task was terminated after three more attempts of the dyad partner. Dyads with five or fewer slides of the figure were excluded from the study.

Procedure

Parents received questionnaires by mail and handed them in during the session or returned them by mail. The session started with 5–30 minutes of free play during which the children could familiarize themselves to each other and the experimenters. The duration of free play varied across age groups, as older children needed less time for this phase. The introductory phase was followed by the peer cooperation task for 5 minutes. Parents were instructed to minimize their interactions with the child and, if the child was clinging to the parent, to respond in ways to stimulate play without helping them with the task. The cooperation task was terminated once due to too much interference of a parent. Parents were not present during the sessions of the 4-year-olds, as these took place at school. Overall, sessions lasted for 20–45 minutes. The 2- and 3-year-old children received either a book or 10 Euros 'for their piggy bank' as a thank you for participation. Teachers of the 4-year-olds were offered a picture book for the participation with their class. The entire session was videotaped with two cameras to allow offline coding.

Measures

Cooperation attempts were coded as successful if both the child who inserted the figure into the tube and the child who held the swimming pool chose the same tube. Cooperation attempts were coded as unsuccessful if children chose different tubes or if one child performed the task alone, resulting in the figure falling on the floor. For each trial (defined as a 'slide' of the figure through the tube), it was coded whether cooperation was successful or not. To control for the total number of attempts, the data were transformed into a percentage of success on the task for each dyad. The recordings of 18 of the 140 dyads (13%) were double-coded by a second observer. Cohen's Kappa (*K*) was .92 on average (range .76–1.00).

The interactive behavior of each child was coded separately using a coding scheme based on Hunnius, Bekkering and Cillessen (2009). Behaviors were divided into *affiliative* behaviors that supported the interaction and *antagonistic* behaviors that obstructed it (see Table 2.1). Repeated occurrence of the same behavior category was coded as a new occurrence if the child had stopped the behavior before showing it again, and in the case of verbal behavior, once for each utterance. The first author trained eight independent coders in the coding scheme. Coders were regularly monitored, as one in six videos was double coded blindly by the trainer. They had to have more than 70% agreement based on both frequency and sequence of codes within a 3-second distance to allow the coder to continue, which was always the case (K = .75, range .45–1.00).

Table 2.1. Coding Scheme for the Interactive Behavior during the Peer Cooperation Task

Affiliative behaviors	
Sharing	Hands over the Playmobil figure/swimming pool to the peer
Helping	Gives task directions, helps the peer with the task, or prepares peer that the figure is going to slide
Directing	Directs the behavior of the peer by assigning a role to the peer
Ask material/ procedure	Asks for figure/swimming pool, asks for a turn, or asks what the peer wants
Ask for help	Asks the peer for help
Agree	Agrees verbally to a question of the peer
Positive response	Responds by laughing, applauding or making positive comments to the behavior of the peer or to the successful cooperation
Antagonistic behaviors	
Taking away	Snatches away the figure/swimming pool out the hands of the peer, or aims to do so
Competing	Races against the peer to get the figure or the swimming pool
Claiming/hinder	Claims one of the objects, refuses to share an object (by turning away or hiding the object), hinders the peer to insert the figure into the tube by placing the hands over the tube
Protesting	Protests as a reaction to peer's behavior or question
Aggression	Aggressive acts toward the peer or material (e.g., pushing, throwing the figure on the ground)
Neglecting	Does not respond to approaches (e.g., sharing), directions or a question of the peer

Child characteristics and peer experiences were measured through parent questionnaires. Social competence was measured with the Dutch version of the competence scale of the Infant Toddler Social Emotional Assessment (ITSEA; Carter, & Briggs-Cowan, 2000a, 2000b). This scale has 37 items rated on a 3-point scale, such as 'Takes turns when playing with others.' The ITSEA is reliable (Carter & Briggs-Cowan, 2000a) and is indicative of children's social competence in daily life, as it is related to independent evaluator ratings of observed child behavior (Carter et al., 2003). Originally, the scale was developed for 12- to 36-month-old infants. For the sake of comparability between age groups, we administered it also to the 3- and 4-year-old participants. Nine items were slightly adapted to fit the older age group. For example, ‘Quiets down when you say “Shh”’ was changed into ‘Quiets down when you ask.’ In our sample, the internal consistency of the scale for the 2-year-olds was .84, and the internal consistency of the adapted scale was .86 for the 3-year-olds and .84 for the 4-year-olds.

Temperament was measured for the 3- and 4-year-olds with the very short form of the Children’s Behavior Questionnaires (CBQ; Putnam & Rothbart, 2006) and for the 2-year-olds with the very short form of the Early Childhood Behavior Questionnaire (ECBQ; Putnam, Jacobs, Garstein, & Rothbart, 2010). The questionnaires included three 12-item scales: negative affectivity, surgency, and effortful control. All items were rated on a 7-point scale. Reliabilities of both the CBQ and ECBQ short forms are good and fit a three-factor model (Putnam et al., 2010; Putnam & Rothbart, 2006). This measure was validated by comparing it to scores of children’s behavior in standardized lab tests for temperament (Gagne, van Hulle, Aksan, Essex, & Goldsmith, 2011). We constructed Dutch versions of the questionnaires using Behling and Law’s (2000) procedure of translation and back translation until agreement was reached. In our sample, internal consistencies of the surgency scale for 2-, 3-, and 4-year-olds, respectively, were .67, .63, and .58; of negative affect were .75, .55, and .73; and of effortful control were .78, .71, and .73.

Parents indicated the number and age of the child’s siblings, and whether and how many days per week the child attended child care. As some children attended multiple forms of care, all formal child care forms were combined to determine the total number of days a week each child attended care. Informal child care with little or no peer contact (such as a private nanny or baby sitter) was not taken into account. In the Netherlands, children commonly attend child care for maximally 11 hours per day on several weekdays from the age of 3 months on. It is less common that a child attends care for five full days per week (te Riele, 2006).

RESULTS

Age Differences in Cooperation Success

During 5 minutes of play, the 2-year-old dyads let the Playmobil figure slide through the tube on average 13.3 (*SD* = 4.6) times. The 3-year-old and 4-year-old dyads did so 17.2 (*SD* = 4.8) and 18.5 (*SD* = 4.0) times, respectively. The three age groups were compared on the percentage of coordinated trials. Successful cooperation made up 22% (*SD* = 26%) of the trials for the 2-year-old dyads; 3- and 4-year-old dyads performed

Table 2.2. Frequency of Interactive Behavior per Minute as Coded per Individual and Intraclass Correlations

	2-year-olds (N = 136)			3-year-olds (N = 74)			4-year-olds (N = 70)		
	Frequency	*SD*	ICC	Frequency	*SD*	ICC	Frequency	*SD*	ICC
Affiliative behavior	1.20	1.17	.35*	2.14	2.20	.17	3.34	2.19	.33
Sharing	.20	.33		.23	.37		.43	.45	
Helping	.44[a]	.57		.41	.67		.33	.35	
Directing				.57	1.05		.89	1.01	
Ask material/ procedure	.17	.30		.14	.24		.33	.42	
Ask for help	.12	.26		.05	.13		.01	.04	
Agree	.08	.20		.05	.12		.18	.30	
Positive response	.18	.37		.68	.86		1.17	1.08	
Antagonistic behaviors	1.68	1.41	.73*	1.04	.93	.47*	1.11	.96	.43
Taking away	.25	.41		.13	.20		.18	.24	
Competing	.78	.61		.15	.20		.09	.16	
Claiming/hinder	.43	.70		.41	.47		.41	.46	
Protesting	.15	.31		.25	.41		.35	.51	
Aggression	.04	.13		.03	.11		.01	.06	
Neglecting	.04	.14		.06	.21		.07	.23	

Note. ICC = intraclass correlation.

[a] For the 2-year-olds the categories helping and directing were taken together, as at this age children's vocabulary was not developed enough to make a distinction between helping and directing.

* $p < .05$.

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better with average scores of 63% (*SD* = 30%) and 79% (*SD* = 14%), respectively. The ANOVA on success was significant, $F(2, 132) = 68.56$, $p < .001$, $\eta^2 = .51$. Post-hoc Bonferroni analyses indicated that 3-year-olds performed better than 2-year-olds, $p < .001$, and 4-year-olds performed better than both 2-year-olds and 3-year-olds, $p < .001$ and $p = .03$, respectively.

Interactive Behavior

Table 2.2 shows the average number of individual affiliative and antagonistic behaviors per minute by age group. As both dyad partners might have influenced each other's behavior during the task, intraclass correlations (ICC) were calculated for the total amounts of affiliative and antagonistic behaviors. For 2-year-olds, the amount of affiliative behaviors of the dyad partners were positively related, $r = .35$, $p = .05$. Intraclass correlations for antagonistic behaviors were positive and significant for the 2- and 3-year-olds, $r = .73$, $p < .001$, and $r = .47$, $p = .03$, respectively, and marginally significant for the 4-year-olds, $r = .43$, $p = .05$.

Child Characteristics and Peer Experiences

Table 2.3 shows that older children were more socially competent, with post-hoc Bonferroni tests indicating a difference between 2- and 4-year-olds ($p = .01$). Age groups also differed in surgency and negative affectivity, with a significant difference between 2- vs. 3- and 4-year-olds (*p*s < .001). There was also an age difference in the number of children with a sibling, with a significant difference between 2- and 4-year-olds ($p = .02$). There were no age differences in effortful control or days attending child care.

Table 2.4 shows that surgency and negative affectivity were related to interactive behavior in the task. Moreover, among 4-year-olds social competence was related to affiliative behavior, child care attendance, and percentage of cooperation success. For 3-year-old children there was a negative association between days attending child care and success on the cooperation task.

Associations with Affiliative Behavior and Cooperation Success

To examine the associations of child characteristics and peer experiences with interactive behavior and cooperation success, structural equation modeling was conducted using AMOS 20.0 (IBM SPSS, Armonk, NY, USA). We used the mutual influence model to examine the effects of the predictors on the outcomes while taking the dyadic structure and mutual influence between the dyad partners into

Table 2.3. Descriptive Statistics of Child Characteristics and Peer Experience Variables and Test of Age Differences

	2-year-olds (N = 125)		3-year-olds (N = 65)		4-year-olds (N = 59)				
	Mean (*SD*)		Mean (*SD*)		Mean (*SD*)		*F* (2, 248)	*p*	η^2
Social competence	1.55	(.21)	1.60	(.22)	1.65	(.19)	4.41	.01	.03
Temperament									
Surgency	4.95	(.63)	4.38	(.65)	4.14	(.60)	39.94	< .001	.25
Negative affectivity	2.61	(.68)	3.17	(.83)	3.45	(.75)	30.16	< .001	.20
Effortful control	4.98	(.63)	5.00	(.76)	5.07	(.66)	.35	.70	<.01
Siblings	.62	(.49)	.77	(.43)	.81	(.39)	4.66	.01	.04
Days child care	1.85	(.89)	2.15	(.82)	1.86	(.82)	2.85	.06	.02

Note. * $p < .05$.

Table 2.4. Correlations of Child Characteristics and Peer Experience Variables with Cooperation Success and Number of Affiliative and Antagonistic Behaviors per Minute by Age Group

	2-year-olds (N = 126)			3-year-olds (N = 65)			4-year-olds (N = 59)		
	Success	Affiliative	Antagonistic	Success	Affiliative	Antagonistic	Success	Affiliative	Antagonistic
Social competence	.08	.08	.01	.14	.06	.07	.11	.30*	.20
Temperament									
Surgency	-.03	.29*	-.01	.02	.09	.16	-.04	.35*	.26*
Negative affectivity	.00	-.14	-.18*	-.17	-.11	.04	-.16	-.25	-.20
Effortful control	.01	.02	.05	.21	.08	-.12	.21	-.03	-.13
Siblings	.05	.02	-.06	-.09	.13	.03	.02	.11	.13
Days child care	-.09	-.01	-.02	-.13	-.02	-.04	.29*	.32*	.04

Note. * $p < .05$.

account (Kenny, Kashy, & Cook, 2006). Hereby, means, variances, covariances, and paths were set equal between dyad members, as the two children in each dyad were interchangeable. Multi-group modeling for affiliative and antagonistic behaviors separately was used to test whether associations differed between age groups.

Figure 2.2 presents the best fitting models resulting from the model with affiliative behavior. For all age groups, there were significant effects of surgency, ß = .21, $p < .001$, and negative affectivity, ß = -.14, $p = .009$, on affiliative behavior. More surgency and less negative affectivity were related to more affiliative behavior. Girls showed more affiliative behaviors than boys, ß = .21, $p = .02$. There was also an effect of effortful control on cooperation success, ß = .08, $p = .01$. More effortful control was related to more cooperation success. For the 2- and 3-year-olds, more affiliative behavior predicted more cooperation success, ß = .21, $p < .001$ (see Figure 2.2a). For the 4-year-olds, there was a positive effect of child care on cooperation success, ß = .16, $p < .001$ (see Figure 2.2b). For cooperation success, the best fitting models explained 8.6%, 18.6%, and 39.6% of the variance for the 2-, 3-, and 4-year-old groups, respectively. For affiliative behavior, the best fitting models explained 15.8%, 5.2%, and 5.5%, respectively.

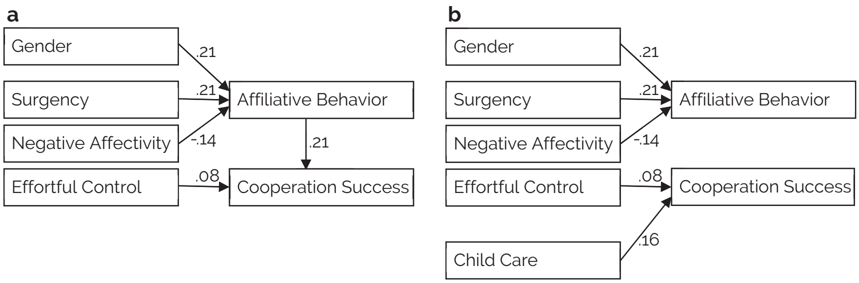


Figure 2.2. The models with the best fit of the association between child characteristics and peer experiences with affiliative behavior and cooperation success for 2- and 3-year-olds (a) and for 4-year-olds (b). All covariances, insignificant paths, and the paths between child care and cooperation success and affiliative behavior are kept in the model but restricted to zero.

To attain the best fitting models, we started from the most constrained model, due to power problems and no specific hypothesis about age differences. We began with a pretest with all paths set to zero and consecutively tested whether intercepts, means, variances, and covariances differed between age groups. Results showed that the model was best with the means for effortful control, child care, and gender, all variances except for negative affectivity and the error terms, and all covariances restricted across age. Moreover, part of the covariances could be set to zero.

With these restrictions from the pre-test, in step 1 we examined the path from affiliative behavior to cooperation success (Figure 2.3, path f/f'). Models without this path or with this path restricted across age did not fit better than a model in which this path had a separate value for each age group, $\chi^2(3) = 11.28$, $p = .01$, and $\chi^2(2) = 8.58$, $p = .01$, respectively. Thus, the association between affiliative behavior and cooperation success differed across age.

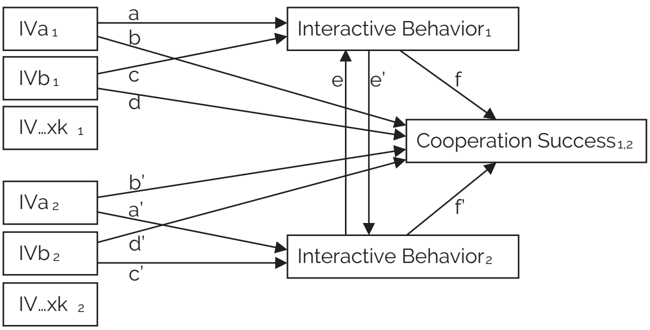


Figure 2.3. Simplified dyadic model of the association between independent variables (IV) and interactive behavior and cooperation success, with a_1 assigned to variables for the first child in the dyad, a_2 for variables of the second child in the dyad, and $a_{1,2}$ for dyadic variables. Paths with equal letters are set equal between dyad members, with the letter without accent indicating the path for child 1, and with accent indicating the path for child 2.

In step 2, we tested for mutual influence of a child's affiliative behavior on the affiliative behavior of the dyad partner (Figure 2.3, path e/e'). This was not the case, as the model with only the path between affiliative behavior and cooperation success was better than models with an additional mutual influence either equal across age, $\chi^2(1) = 2.76$, $p = .10$, or unequal across age, $\chi^2(3) = 3.81$, $p = .28$.

In step 3, model fit was tested for each independent variable separately (Figure 2.3, path a–d/a'–d'). Models with a fixed parameter across age for the paths from surgency, negative affectivity, and gender to affiliative behavior led to a better fit than models with separate values by age or without these paths (see Table 2.5). For surgency and gender, the models with separate values by age fit better than the models without these paths, $\chi^2(2) = 2.63$, $p = .27$, but the models with the path restricted across age fit better, $\chi^2(2) = 2.63$, $p = .27$. The model fit was also better with a separate value for each age group for the paths from child care to cooperation success. The fit of the model with an effect of effortful control on cooperation success when the path was equal across age showed a trend. The path of social competence to affiliative behavior also showed a trend, with a better model fit for the model with the path equal across age as compared with the model with the path unequal across age, $\chi^2(2) = 3.68$, $p = .16$.

Table 2.5. Chi-square Difference Values for the Models With an Independent Variable with Paths Restricted or Unrestricted Across Age

		Affiliative Model		Antagonistic Model	
Independent Variable	Dependent Variable	Restricted across age	Unrestricted across age	Restricted across age	Unrestricted across age
Social Competence	Cooperation Success	2.06	2.07	2.65	3.17
Social Competence	Interactive Behavior	2.84^t	6.51^t	1.31	2.22
Surgency	Cooperation Success	.59	.83	.10	.12
Surgency	Interactive Behavior	16.31*	18.94*	3.15^t	5.92
Negative Affectivity	Cooperation Success	2.13	4.49	2.56	3.91
Negative Affectivity	Interactive Behavior	5.44*	6.80^t	1.78	6.84^t
Effortful Control	Cooperation Success	3.43^t	5.02	3.95*	5.46
Effortful Control	Interactive Behavior	.14	.52	.75	1.90
Siblings	Cooperation Success	.00	1.37	.05	.84
Siblings	Interactive Behavior	.59	1.79	.00	1.42
Child Care	Cooperation Success	.57	7.97*	.43	8.25*
Child Care	Interactive Behavior	.41	6.20	.34	.53
Gender	Cooperation Success	2.53	5.78	3.99*	6.97^t
Gender	Interactive Behavior	5.63*	8.08*	.02	1.31

Note. Each affiliative model is compared with the affiliative model with only the path between affiliative behavior and cooperation success. Each antagonistic model is compared with the antagonistic model with only the path between antagonistic behavior and cooperation success fixed to zero and the mutual influence of the partner's antagonistic behaviors.
* $p < .05$, ^{t} $p < .10$.

In Step 4, we included all significant paths that resulted in a better model fit compared with the model fit with only a path from affiliative behavior to cooperation success, $\chi^2(6) = 36.40$, $p < .001$. This model fit was worse than the model in which the path from effortful control to cooperation success was included, $\chi^2(1) = 6.59$, $p = .01$. Adding the path from social competence to affiliative behavior did not result in a better model fit, $\chi^2(1) = .06$, $p = .80$. We removed social competence and siblings from the model as they did not contribute to better model fit. Furthermore, the model fit with paths equal for 2- and 3-year-olds was better than the previous model, $\chi^2(2) = .15$, $p = .93$. Thus, whereas the model for the 2- and 3-year-olds seemed to be the same, a different model was needed for the 4-year-olds. Moreover, model fit was better with the path from child care to cooperation success set to zero for 2- and 3-year-olds and the path from affiliative behavior to cooperation success set to zero for the 4-year-olds, $\chi^2(2) = 1.87$, $p = .39$.

At the end, the fit of this best fitting model was determined with a chi-squared difference test between the original fit of this model, $\chi^2(234) = 338.84$, $p < .001$, and the fit of the saturated model, $\chi^2(162) = 263.99$, $p < .001$, in which only means, variances and covariances were estimated (see Kenny et al., 2006). The resulting chi-squared difference was $\chi^2(72) = 74.85$, $p = .39$, indicating adequate fit.

Associations with Antagonistic Behavior and Cooperation Success

The result of the multi-group modeling with antagonistic behavior was a model with only a mutual influence effect of antagonistic behavior, ß = .52, $p = .004$, as antagonistic behavior was not related to other variables. The more antagonistic behavior one child of the dyad showed, the more antagonistic behaviors the other child showed. This model explained 33.1%, 0.6%, and 3.1% of the variance in antagonistic behavior for 2-, 3-, and 4-year-olds, respectively.

The model for antagonistic behavior was constructed following the same steps as the model for affiliative behavior. We began the analyses by testing first the path from antagonistic behavior to cooperation success, but the model without this path fit better than a model with this path equal or unequal across age, $\chi^2(1) = 3.69$, $p = .06$, and $\chi^2(3) = 4.75$, $p = .19$, respectively. As mentioned, there was an age-invariant mutual influence effect of antagonistic behavior, $\chi^2(1) = 11.44$, $p = .001$. Including paths from the predictors to antagonistic behavior did not yield better fit (Table 2.5). Therefore, all predictors were removed, resulting in a model with antagonistic behavior and cooperation success included. The chi-squared difference test between the original fit of this model ($\chi^2(13) = 15.82$, $p = .26$) and the fit of the saturated model ($\chi^2(9) = 10.99$, $p = .28$) resulted in adequate fit for this best fitting model, $\chi^2(4) = 4.83$, $p = .31$.

DISCUSSION

In the current study, we investigated peer cooperation among young children of three age groups, examining both quality of interactive behavior and cooperation success. We examined how child characteristics and peer experiences were related to the development of interactive behavior and cooperation success during peer cooperation. Cooperation success showed a strong increase between 2 and 4 years of age. Whereas 2-year-olds coordinated their actions only infrequently, 3- and 4-year-olds were very proficient in cooperation. At first, these findings might seem at odds with Brownell et al. (2006), who found indications of peer cooperation in 27-month-olds. However, in Brownell et al., both children had to pull a handle and thus perform a mutual imitative action, whereas our cooperation task required complementary or reciprocal actions, which might be more difficult (Eckerman & Peterman, 2004; Hunnius et al., 2009). Success on cooperation tasks that require complementary actions has indeed been found to develop only during the third year of life (Ashley & Tomasello, 1998; Brownell, 2011). It is important to consider how cognitive changes might explain differences in task success between the age groups. For example, being able to plan one's actions is an important prerequisite for cooperation (Gerson, Hunnius, & Bekkering, 2013; Obhi & Sebanz, 2011), an ability that develops throughout early childhood (Smyth & Mason, 1997; Zelazo, Carter, Reznick, & Frye, 1997). Moreover, being able to flexibly adapt your behavior in response to the cooperation partner's actions might play an important role (Brownell, 2011; Gerson et al., 2013).

With respect to the association between interactive behavior and cooperation success, we found that children who showed more affiliative behaviors were also more successful on the cooperation task. This is consistent with Ramani (2012) who found that better cooperation was related to more positive communication, such as making suggestions, describing the task goal, and agreeing to a peer's action. The lack of association between interactive behavior and cooperation success for the 4-year-olds might be due to a ceiling effect: the 4-year-old children tended to fail only on purpose or when they made the task more challenging, for example by playing very fast. A more difficult task might have been more appropriate to test the effect of interactive behavior on cooperation success, but would have resulted in higher dropout rates for the younger children.

No association was found between antagonistic behavior and cooperation success at any age. This might be due to the function of antagonistic behavior in young children. On the one hand, antagonistic behavior, like aggression, can negatively affect social functioning (e.g., Hart, DeWolf, Wozniak, & Burts, 1992; NICHD Early Child Care Research Network, 2004b). On the other hand, antagonistic behavior in young children serves a positive social function in peer interaction because it may be a normative part of early social exploration by which children discover how to best interact (Vaughn et al., 2003; Williams et al., 2007, 2010). This double function of antagonistic behavior might explain why we did not find simple positive or negative associations with cooperation success. For example, the antagonistic behavior 'claiming material' might have had a positive social function as by this behavior children explored how they could encourage their peer to take turns and share toys.

The effect of child characteristics on interaction behavior was stable across age. The same child characteristics influenced affiliative behavior during peer cooperation among 2-, 3-, and 4-year-olds. As expected based on earlier research, girls at all ages showed more affiliative behavior than boys. This gender effect can be explained by boys' orientation to competition and dominance (Maccoby, 1990), which may have resulted in less affiliative behavior toward their dyad partner.

We also found that temperamental surgency was positively related to affiliative behavior, whereas negative affectivity was related negatively to affiliative behavior. Children who were more active and extroverted and less shy thus displayed more affiliative behavior. Our relation of surgency with affiliative behavior is not in accordance with Sterry et al. (2010) who found that in school-age children more general activity (surgency) is related to less prosocial behavior. It is possible that surgency has a different effect on peer interaction in younger children. Gunnar, Tout, de Haan, Pierce, and Stansbury (1997) indeed suggested a positive association between surgency and peer interaction in preschool children. They found that children with more surgency (and less negative affectivity) showed fewer negative behaviors, although an association with affiliative behaviors was not found. For negative affectivity, Laible, Carlo, Murphy, Augustine, and Roesch (2014) found that children's negative affectivity at 4 years of age was negatively associated with their prosocial behavior at 9 years. Our findings extend this knowledge by showing that also younger children high in negative affectivity were also less affiliative with peers. There was no direct effect of gender, surgency, or negative affectivity on cooperation success. Therefore, the results suggest that both gender and temperament (surgency and negative affectivity) influence cooperation success via the quality of interactive behavior during the cooperation task.

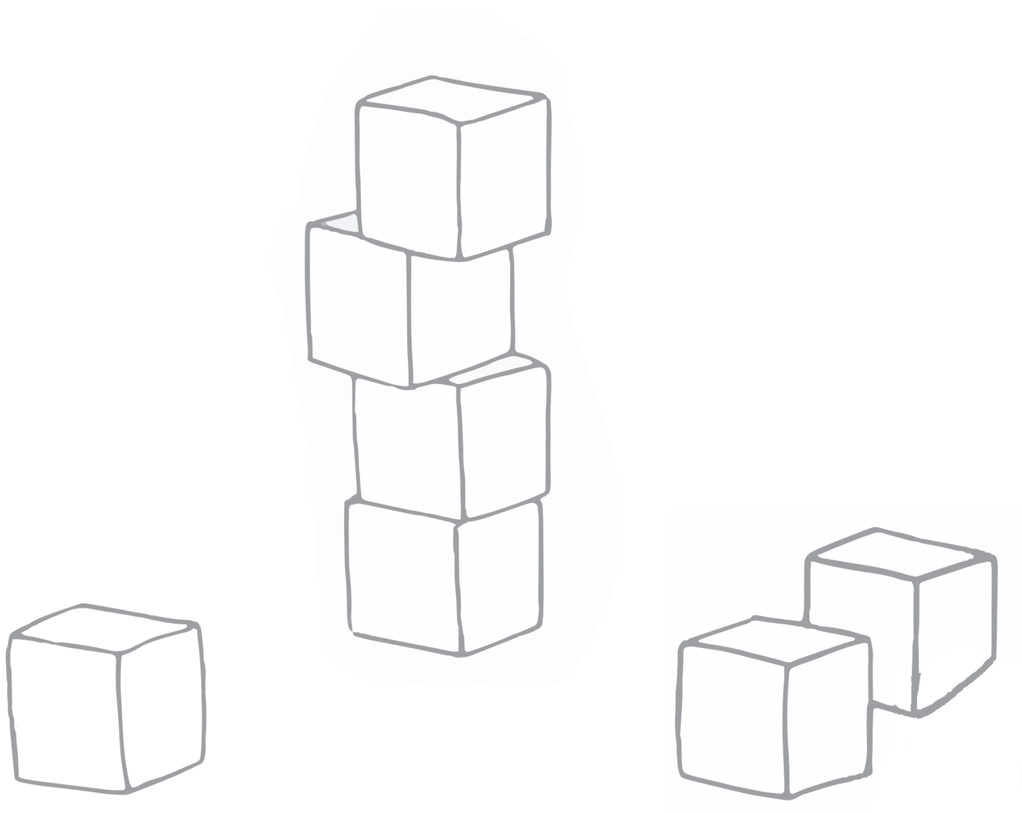
There was also a direct effect of temperament on cooperation success. Children with better effortful control as reported by parents showed more cooperation success. This confirms recent results by Laible et al. (2014) who found a positive association between effortful control and parent-rated cooperative behavior among 4- to 9-year-olds. Although a direct association between effortful control and successful cooperation in younger children has not yet been reported, Kochanska and Knaack (2003) found that 22- to 45-month-old children with better effortful control were also better at internalizing rules at 56 months of age. Being able to internalize rules might be important in early peer cooperation given that children learn from adults that they have to share toys and take turns. As these behaviors were important in our cooperation task, this association between effortful control and internalizing rules could explain our positive association between effortful control and cooperation success.

For peer experiences, no association of siblings with cooperation or interactive behaviors was found. This could be explained by the heterogeneous nature of siblings (see Downey & Condron, 2004), as children often had a sibling too young to fulfill a role as play partner. But cooperation was associated with the time 4-year-olds had spent in child care before entering preschool. This suggests that early peer experiences play an increasingly important role in young children's cooperation across development. A reason for this finding may be that mainly during the last period of child care before entering school, interactions with peers change to more cooperative play. This explanation is supported by Garnier and Latour (1994) who described that, mainly between 40 and 50 months of age, children's play becomes more collaborative and interdependent. Moreover, Stolk et al. (2013) recently found that 5-year-old children who spent more time in child care before entering preschool were better at making communicative adjustments to a fictive 2-year-old child, which could also be relevant in cooperation with a less skilled peer. Children who attend child care possibly had more time to examine different ways of cooperating and to learn how to cooperate successfully with a peer. Further research is needed to clarify this association and see if this advantage for cooperation is only temporary.

No association was found between children's social competence and cooperation. This might be due to how social competence was assessed. We used the ITSEA, which asks parents to judge the social and emotional competence of their child. However, as parents observe their children mainly in family situations, this questionnaire may not be an ideal indicator of social competence in interactions with peers (Reddy, Hay, Murray, & Trevarthen, 1997).

The focus of this study on relevant proximal child and peer environmental predictors of cooperation does not rule out that other, more distal predictors might also be relevant for cooperation development. For example, attachment is related to early social interaction (e.g., Hartup & van Lieshout, 1995). Securely attached children show increased willingness to be involved with others, and better social and emotional capacities (Sroufe, 2005). This might result in more and higher quality peer interactions, which, in turn, might also have a positive impact on cooperation success. However, it is still unclear whether a good mother–infant relationship is a prerequisite for or develops parallel to peer relationships (Hay et al., 2009). Moreover, attachment quality also seems to be influenced by temperament (Rothbart & Ahadi, 1994; van den Boom, 1994), which we assessed. Future studies could include both attachment and temperament and examine how they uniquely contribute to the development of cooperation.

In sum, this study adds to our knowledge of the development of peer cooperation in young children. The findings highlight how rapidly peer cooperation develops in young children and how both child characteristics and peer experiences play a role in it. Initially, children's temperament primarily influences cooperation, but as they grow older, previous peer experiences in child care come into play. A longitudinal study of peer cooperation development from early childhood to school age could provide further insight in the relative influence of child characteristics and peer experiences and their bidirectional influences across development.



Neural Mirroring and Social Interaction: Motor System Involvement During Action Observation Relates to Early Peer Cooperation

H. M. Endedijk
M. Meyer
H. Bekkering
A. H. N. Cillessen
S. Hunnius

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3

ABSTRACT

Whether we hand over objects to someone, play a team sport, or make music together, social interaction often involves interpersonal action coordination, both during instances of cooperation and entrainment. Neural mirroring is thought to play a crucial role in processing other's actions and is therefore considered important for social interaction. Still, to date, it is unknown whether interindividual differences in neural mirroring play a role in interpersonal coordination during different instances of social interaction. A relation between neural mirroring and interpersonal coordination has particularly relevant implications for early childhood, since successful early interaction with peers is predictive of a more favorable social development. We examined the relation between neural mirroring and children's interpersonal coordination during peer interaction using EEG and longitudinal behavioral data. Results showed that 4-year-old children with higher levels of motor system involvement during action observation (as indicated by lower beta-power) were more successful in early peer cooperation. This is the first evidence for a relation between motor system involvement during action observation and interpersonal coordination during other instances of social interaction. The findings suggest that interindividual differences in neural mirroring might underlie interpersonal coordination and thus successful social interaction.

INTRODUCTION

Our daily life contains a multitude of social interactions in which we coordinate our actions with others. The involvement of the mirror system in action perception, monitoring, and prediction (e.g., Bekkering et al., 2009; Kilner, Friston, & Frith, 2007; Southgate, Johnson, Osborne, & Csibra, 2009; Stapel, Hunnius, van Elk, & Bekkering, 2010) is thought to help us prepare and execute our own actions in coordination with others (Kourtis, Sebanz, & Knoblich, 2013; Sebanz et al., 2006). Converging neuroimaging evidence has shown that our motor system becomes activated both when performing an action, and when observing an action (Marshall & Meltzoff, 2011; Rizzolatti & Craighero, 2004; Rizzolatti & Fogassi, 2014). This neural overlap between action production and perception has been called *neural mirroring* (e.g., Hari & Kujala, 2009). It has been suggested that neural mirroring provides the neurocognitive basis for processing others' actions and therefore plays a crucial role in successful interpersonal coordination during social interaction (Bekkering et al., 2009; Hari & Kujala, 2009).

Previous findings support this hypothesis of a close relation between neural mirroring and interpersonal coordination. For instance, adults who showed more motor system involvement when observing a partner's movements in a finger tapping task also coordinated their movements better with the partner (Naeem, Prasad, Watson, & Kelso, 2012). In social interaction especially complementary actions are relevant (Bekkering et al., 2009), which also were related to motor involvement of the neural motor areas during action observation (Ménoret et al., 2014). Comparable findings are present for children, as young children who mirrored an adult action partner more than another adult in a turn-taking game made fewer errors in interpersonal coordination during that game (Meyer et al., 2011). Similarly, recently, Fillipi et al. (2016) found that elevated levels of mirroring in 7-month-old infants predicted their imitation of others' toy choices. These findings support a link between neural mirroring and interpersonal coordination within the same laboratory task. However, the degree to which interindividual differences in neural mirroring might be a stable characteristic and support the success in various instances of social interaction is unknown.

While the role of interindividual differences in neural mirroring for interpersonal coordination is unclear, studies of social cognition (e.g., empathy, perspective taking) highlight a role of mirroring for social skills that are not task-specific. In adults, neural mirroring is related to higher levels of perspective taking (Woodruff, Martin, & Bilyk, 2011), empathy (Gazzola, Aziz-Zadeh, & Keysers, 2006; Hooker, Verosky, Germine, Knight, & D'Esposito, 2010; Kaplan & Iacoboni, 2006), and social competence as assessed with questionnaires (Pfeifer, Iacoboni, Mazziotta, & Dapretto, 2008). In this study, we investigated whether interindividual differences in neural mirroring also might play a role in interpersonal coordination during social interactions outside the specific task.

In social interaction, two types of interpersonal coordination occur often: cooperation and entrainment. While in *cooperation*, coordination is planned and typically involves a goal-directed task, in *entrainment*, coordination emerges spontaneously without a joint goal (Knoblich et al., 2011). For instance, soccer players cooperate by keeping track of each other and adjusting their positions accordingly to obtain the ball and shoot it at the goal. During applause, on the other hand, people entrain by coordinating their clapping behavior spontaneously. In cooperation, it is important to monitor others' actions with respect to the achievement of the common goal. In entrainment the focus rather is on the monitoring of the others' movements. Importantly, both the observation of movements and goal-directed actions were found to activate the human mirror system (Rizzolatti & Craighero, 2004; Rizzolatti & Fogassi, 2014).

Activation of the mirror system during action observation already has been demonstrated in infancy (Marshall & Meltzoff, 2011). Investigating the relation between neural mirroring and interpersonal coordination is especially important in early childhood, since proficiency in social interaction at this age, mainly with peers, predicts social competence later in life (e.g., Hay et al., 2009; Rubin et al., 2006). Children already demonstrate action coordination with peers in toddlerhood (e.g., Ashley & Tomasello, 1998; Brownell, 2011; Endedijk, Cillessen, et al., 2015 (Chapter 2); Hunnius et al., 2009). During the preschool years, children's interpersonal coordination continues to develop, as they begin to respond more quickly to the behavior of others and become more stable in coordination, both in cooperation (Ashley & Tomasello, 1998; Endedijk, Cillessen, et al., 2015 (Chapter 2); Fletcher et al., 2012) and in entrainment tasks (Endedijk, Ramenzoni, et al., 2015 (Chapter 1)). Throughout early childhood, children gain ample experience with interpersonal coordination. Children who face difficulties with social interactions early in life more often experience rejection by peers later on (Friedlmeier, 2009; NICHD Early Child Care Research Network, 2008) with subsequent negative consequences for their social functioning in adolescence and adulthood (Bagwell et al., 1998). Clarifying the processes involved in early interpersonal coordination with peers is very important for understanding social development.

The current study examined the relation between interindividual differences in neural mirroring and young children's social interaction skills. Children's neural mirroring was assessed by measuring oscillatory brain activity (by means of EEG) during action observation. In particular, the mu- and beta-frequency bands over motor areas have been associated with motor system involvement during action observation (cf. Meyer et al., 2011; Pfurtscheller & Lopes da Silva, 1999; Pineda, 2008; Saby & Marshall, 2012; Vanderwert, Fox, & Ferrari, 2013). To investigate the relation between neural mirroring and interpersonal coordination with peers, motor system involvement during action observation was assessed in 4-year-old children. As part of a longitudinal study their interpersonal coordination had been assessed earlier at 28, 36, and 44 months, in a cooperation task and in an entrainment task with different peers. Based on previous research suggesting the functional involvement of neural mirroring during interpersonal coordination (Meyer et al., 2011; Naeem et al., 2012), we hypothesized that interindividual differences in children's neural mirroring of others' actions would be associated with both forms of interpersonal coordination (cooperation and entrainment).

METHOD

Participants

The sample consisted of 29 children (10 boys) who participated in an EEG experiment at 52 months of age (*M* = 52.48, *SD* = 1.94). Interpersonal coordination with peers had been assessed in play sessions at 28 months (*M* = 27.96, *SD* = .33), 36 months (*M* = 35.98, *SD* = .34), and 44 months (*M* = 43.83, *SD* = .34). The participants were part of a larger sample of 181 children whose social development was studied longitudinally from toddlerhood to early school age. Children were selected from the larger sample if they had participated in three play sessions (i.e. had not missed a session) and were willing to participate in EEG research. The play sessions took place in the lab with an unfamiliar same-gender peer (also of the longitudinal study sample), each play session with a different peer. All children were Dutch and from mixed socioeconomic backgrounds. All participants were healthy and had no indications of atypical development. Parents were informed of the study and gave written consent.

After each testing session, children received a book or a small amount of money "for their piggy bank" as a thank you for participation.

Procedure

The EEG session took approximately 60 minutes including familiarization with the experimenters, preparing the EEG cap, and the measurement itself (see Action Observation Task). During testing, children were videotaped from two visual angles (with one camera directed at the child's upper body and the other one at the child's legs) in order to remove trials in which the child was moving or did not pay attention.

Previously, children had participated in three play sessions to assess their interpersonal coordination (see Cooperation Task and Entrainment Task). The play sessions started with 10 to 30 minutes of free play during which children got familiarized with each other and the experimenters. The introductory phase was followed by the cooperation task, which took about 5 minutes. The entrainment task followed with a maximum duration of 5 minutes. Parents were instructed to minimize their interactions with their child and, if the child was clinging to them, respond in ways to stimulate involvement in the session without helping with the tasks. Each session lasted about 45 minutes and was videotaped from two visual angles using two video cameras.

Action Observation Task

To assess children's individual levels of neural mirroring, EEG was measured while they watched videos of actions. The task had two conditions: action observation and abstract movement observation. In the action observation condition (Figure 3.1, top row), children observed a video of an adult performing different actions on objects (e.g., stacking cups or moving a toy car into a garage). In the abstract movement condition (Figure 3.1, bottom row), children observed abstract shapes moving across the screen, similar to a screensaver. This abstract movement condition was included to control for non-human movement perception. There were six action videos and six abstract movement videos, each lasting approximately 7 seconds. During both action observation and abstract movement observation condition, each video was repeated three times and preceded by a 1000 ms fixation cross that functioned as baseline (see Figure 3.1). The action observation condition was run twice with two different task instructions (to imitate the action vs. to name the color of the object; blocked and counterbalanced between children) as part of a different study. Thus, each action observation video was shown six times in total and each abstract movement video three times. After two action observation videos, one abstract movement observation video was shown. To assess children's neural activity during action execution, EEG also was recorded while children imitated the actions after having observed them.

Figure 3.1. Example of the action observation (top row) and the abstract movement observation (bottom row) stimuli preceded by the baseline (fixation cross).

EEG recordings were conducted using child-sized EEG caps with 32 electrode sites on the scalp. The Ag/AgCl active electrodes were placed in an actiCap (Brain Products GmbH, Munick, Germany), arranged according to the 10–20 system, and referenced to electrode FCz over the central midline. The signal was amplified using a 32-channel BrainAmp DC EEG amplifier, band-pass filtered (.1–125 Hz), and digitized at 500 Hz. We strived to keep all impedances below 60 kΩ.

Analogous to previous studies (see Marshall & Meltzoff, 2011, for a review), we analyzed motor system activity by means of mu- and beta-oscillatory power over sensorimotor areas. Motor system involvement was analyzed during action observation, abstract movement observation, and action execution. Data analysis was performed using FieldTrip (Oostenveld, Fries, Maris, & Schoffelen, 2011), an open source Matlab toolbox (The MatWorks, Inc, Natick, Minnesota, USA). All data was divided in 1-second segments. Segments during which children moved or did not look at the stimulus display were removed. We visually inspected the remaining segments to exclude EEG artifacts (such as noisy channels or eye blinks). One child was removed from the analyses due to the lack of baseline trials during the abstract movement observation condition. On average, per child 120 segments remained for the action observation (range 33–246), 38 segments for the abstract movement observation (range 4–81), 12 segments for the baseline preceding the action observation stimuli (range 3–24), and 5 segments for the baseline preceding the abstract movement stimuli (range 1–12). A DFT filter was used to remove line noise from the data, and for each segment we took out potential offset differences by subtracting the mean signal of the entire trial from the signal at each time point. We then calculated spectral power estimates using the Fast Fourier transform in combination with a Hanning taper.

Based on previous research (see Pfurtscheller & Lopes da Silva, 1999), we focused our analyses on electrodes over motor cortices (C3, C4). To control for interindividual differences in absolute power due to differences in scalp thickness and electrode impedance, the ratio of power during the condition relative to baseline (fixation cross) was computed for each condition. Since these ratios were not normally distributed, a log transformation was applied. These scores were used to indicate children's motor system involvement in each condition (action observation, abstract movement observation) and during action execution. A smaller log ratio indicated more suppression in a condition compared with baseline. Based on the action execution ratio, the sample-specific mu- and beta-frequency range was identified (see Neural Mirroring). Normalized power values were pooled over the central electrodes (C3, C4) per condition in the identified mu- and beta-frequency bands for further analysis.

Cooperation Task

The cooperation task was a peer version of Warneken et al.'s (2006) double-tube task. The setup consisted of two 1-meter-long tubes mounted in parallel on a box with a 45-degree incline (see Figure 3.2a). The children were given a Playmobil figure (Geobra Brandstätter GmbH & Co.KG., Zirndorf, Germany) in a swimsuit and a small swimming pool. They were instructed that the figure wanted to go through the sliding tube to the swimming pool. Because the tubes were too long for one child to simultaneously hold the swimming pool and insert the figure into the tube, the two children had to cooperate to perform the task successfully. A detailed description of the task can be found in Endedijk, Cillessen, Cox, Bekkering, and Hunnius (2015 (Chapter 2)).

a
b

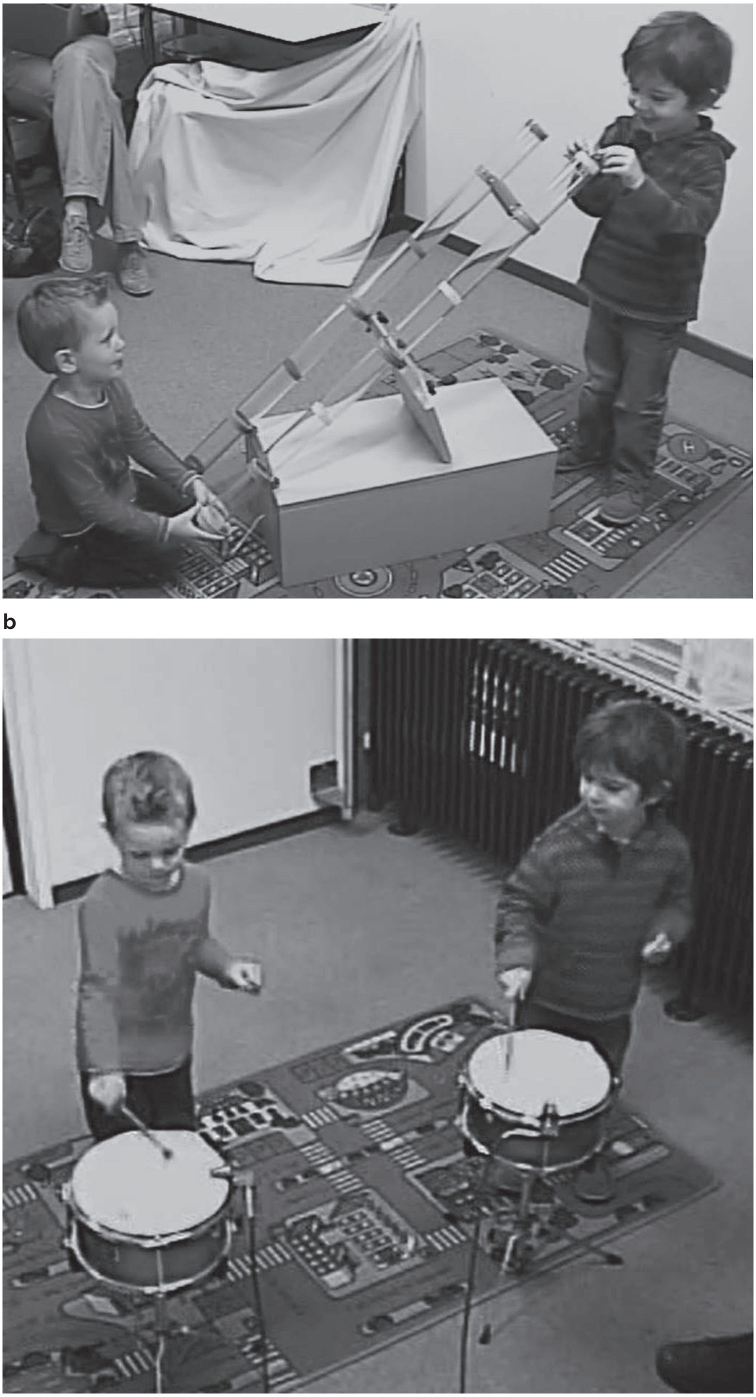


Figure 3.2. Children performing the cooperation task (a) and entrainment task (b).

Each child's behavior was coded off-line from the video recordings. For each trial (defined as a slide of the figure through the tube), it was coded whether cooperation was successful or not. Cooperation trials were coded as successful if both the child who inserted the figure into the tube and the child who held the swimming pool chose the same tube. Cooperation trials were coded as unsuccessful if children chose different tubes or if one child performed the task alone, resulting in the figure falling on the floor. To control for the total number of trials, the data were transformed into a proportion of success on the task for each dyad. For the longitudinal study, the recordings of 20% of the dyads at each time point were coded by two observers. Cohen's kappa was .94 on average (SD = .11).

Entrainment Task

For the entrainment task two 10-inch drums of a Hayman children's drum set (Hayman, London) and two plastic sticks were used (see Figure 3.2b). The drums were placed on a stand that could be adjusted to the height of each child so that they could comfortably drum in standing position. The drums were connected via piezo contact microphones placed on the drumheads to collect MIDI data via an Alesis D4 drum module (Alesis Innovations, Cumberland, RI). Performances were recorded with Logic Express (Apple Inc, Cupertino, CA). Children were instructed separately to start drumming and did not receive any instructions about drumming together or coordinating their drumming with their dyad partner.

Cross-correlations commonly are used in interpersonal coordination studies to investigate entrainment (Repp, 2005). We calculated maximum cross-correlations that indicated how a child's hits best related to their partner's hits rhythmically across time. For this purpose, the time between the hits produced by each child were measured. Time series of these inter-tap-intervals of the two children were shifted alongside each other to find the highest correlation between the two time series. Thereby, the maximum cross-correlation measure describes the coordination of children's rhythmic behaviors.

Analyses

To examine whether interpersonal coordination predicted motor system involvement during action observation (a proxy for neural mirroring), two hierarchical regressions were run, one predicting normalized mu-power and one predicting normalized beta-band power during action observation. To control for motor system involvement due to non-human movement, the normalized power during observation of abstract movement was entered in Step 1 of each regression. In Step 2 of each regression, the measures of interpersonal coordination were entered: the proportion of coordinated trials during cooperation, and the maximum cross-correlation during entrainment. The scores for these two variables were standardized for each play session and averaged across the three sessions, resulting in measures of interpersonal coordination aggregated over sessions and interaction partners. These three averaged z-scores were entered in Step 2 of the regression analysis.

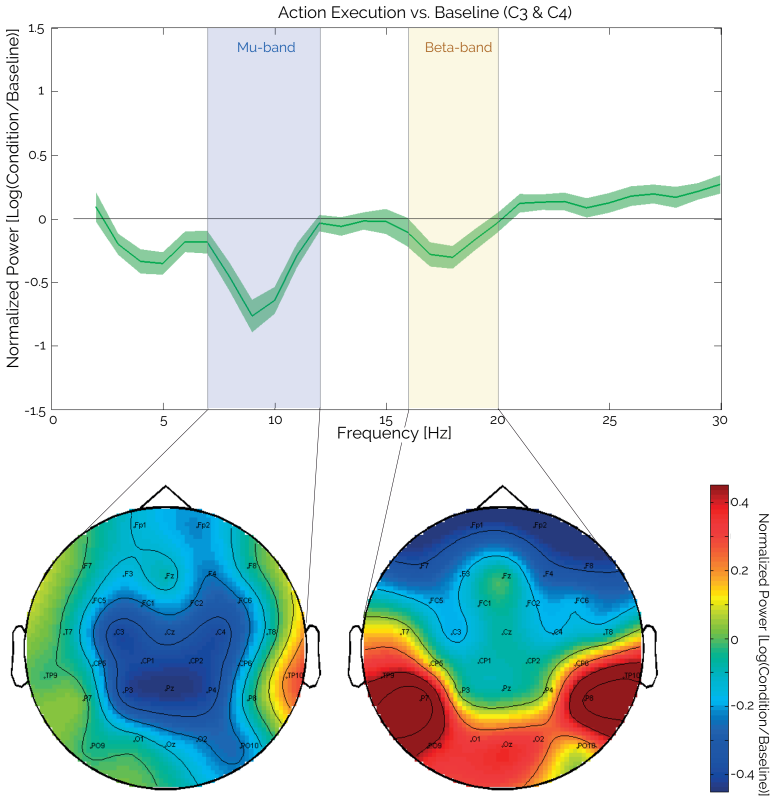


Figure 3.3. Top: Normalized power represented as a function of frequency (Hz) with the left blue-shaded area indicating the selected mu-frequency band (7–12 Hz), and the right yellow-shaded area indicating the selected beta-frequency band (16–20 Hz). Negative normalized power values represent suppression during action execution with respect to baseline. Bottom: The topographic distribution of the normalized power in mu- and beta-frequency bands during action execution, with warm colors representing higher normalized power (enhancement) and cooler colors representing lower power (suppression).

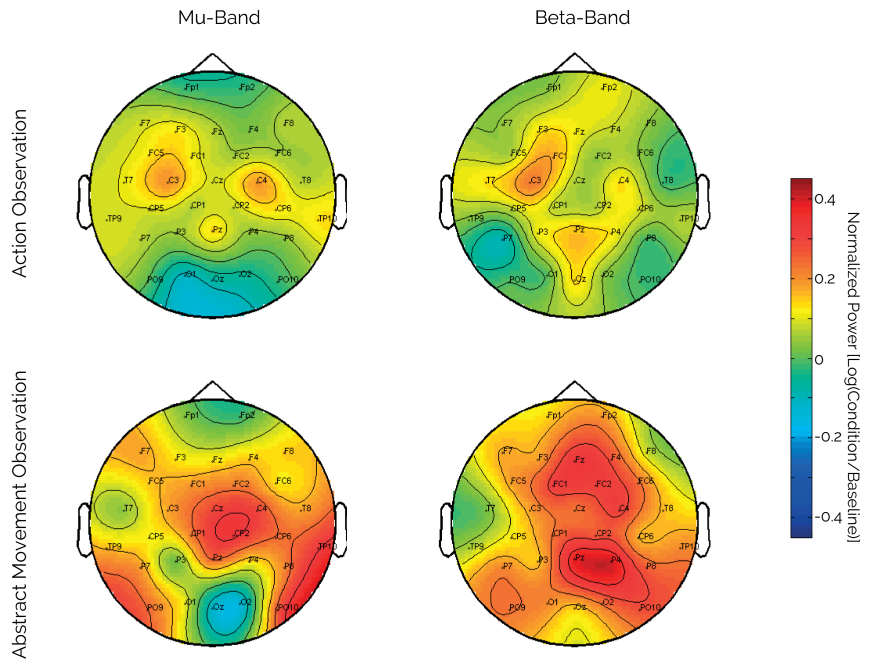


Figure 3.4. Topographic distribution of normalized power in mu- (left) and beta-frequency bands (right) during action observation (top row) and abstract movement observation (bottom row). Warm colors represent higher normalized power (enhancement) for the condition as compared with the baseline and cooler colors represent lower power (suppression) for the condition as compared with the baseline.

Table 3.1. Stepwise Regression Analysis With Normalized Mu and Beta Power Values During Action Observation as Dependent Variables, and Normalized Mu and Beta Power Values During Abstract Movement Observation, Cooperation Performance and Entrainment Performance as Independent Variables

	Mu (7–12 Hz)			Beta (16–20 Hz)		
	R^2	β	*p*	R^2	β	*p*
Step 1						
Abstract movement observation		.46	.02*		.29	.15
Total	.22		.02*	.09		.15
Step 2						
Abstract movement observation		.48	.03*		.17	.38
Proportion coordinated trials		.14	.47		-.52	.01*
Maximum cross-correlation		.05	.79		.19	.31
Total	.24		.12	.39		.02*

Note. * $p < .05$.

RESULTS

Neural Mirroring

Based on the observed suppression of power during action execution (see Figure 3.3, top), the frequency bands were identified on the basis of the grand average as follows: mu from 7 to 12 Hz and beta from 16 to 20 Hz. The topographic distribution of these frequency bands supports the a-priori selection of electrodes over motor cortices (see Figure 3.3, bottom).

The analysis of these specified frequency bands yielded positive normalized power values for both mu and beta during action observation, M = .23, SD = .28, and M = .20, SD = .31, and abstract movement observation, M = .25, SD = .44, and M = .22, SD = .44, indicating relatively more power during experimental conditions than at baseline. Similar to action execution, the topographic distribution of normalized power in mu- and beta-frequency bands showed a relatively confined pattern of activation overlaying motor cortices (especially at electrode sites C3 and C4) during action observation (Figure 3.4, top row). The topographic distribution during abstract movement observation appeared less confined but more widespread along the midline (Figure 3.4, bottom row).

Relation Between Neural Mirroring and Interpersonal Coordination

Table 3.1 summarizes the results of the hierarchical regressions. In step 1, motor system involvement during abstract movement observation was related to action observation values for the mu-frequency band, but not for the beta-frequency band. Adding the measures of cooperation and entrainment in Step 2 resulted in a significantly better model for the beta-frequency band, F_{change} (2, 21) = 5.14, p = .02, ΔR^2 = .39, but not for the mu-frequency band, F_{change} (2, 21) = .31, p = .74, ΔR^2 = .02. For beta, while controlling for non-human movement, power reduction was strongly related to children's performance on the cooperation task (β = -.52, p = .01). Children who were more successful in cooperation with peers also showed more involvement of the motor system during action observation. There was no significant relation between entrainment and beta-band power.

DISCUSSION

In this study, we examined the relation between interindividual differences in neural mirroring in young children and their social interaction with peers in a cooperation and an entrainment task. We found that young children who showed more motor system involvement when observing others' actions (as indicated by a relative reduction in beta power), showed better cooperation skills with peers. The explained variance was high, suggesting that interindividual differences in mirroring are relevant for interpersonal coordination with peers in early childhood.

The relation between motor system involvement during action observation and children's peer coordination is consistent with previous findings that mirroring is related to more reliable imitation (Bernier, Dawson, Webb, & Murias, 2007; Filippi et al., 2016; Warreyn et al., 2013), better interpersonal coordination of finger movements (Naeem et al., 2012), and fewer turn-taking errors (Meyer et al., 2011). However, these previous studies measured neural mirroring and behavioral performance during the same instance of social interaction (i.e. one laboratory task) and thus did not address whether this relation is task-specific or reflects interindividual differences that generalize to social interactions outside the specific task.

To capture various forms of peer interaction, we investigated two types of interpersonal coordination: goal-directed cooperation, and entrainment without an overt common goal. We found that neural mirroring was related to children's performance in the cooperation task but not in the entrainment task. This is consistent with previous research that highlighted the importance of goals for action mirroring (Koski et al., 2002). Bekkering et al. (2009) argued that monitoring and predicting another person's goal rather than their movements is important for interpersonal coordination because it often requires co-actors to perform different movements to achieve a common goal. In the current cooperation task also, children had to assume complementary roles that required monitoring of each other's actions.

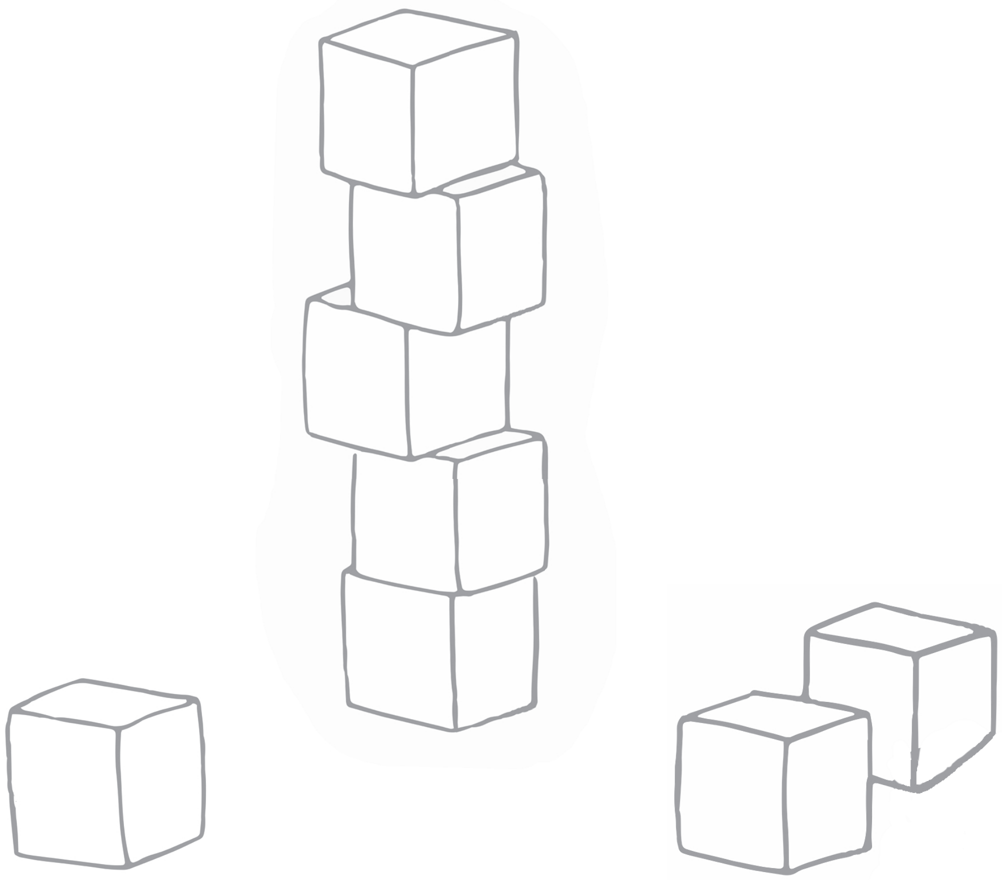
The observed link between neural mirroring and cooperation was evident for beta power (16–20 Hz). For mu power (7–12 Hz), however, no indication for such a relation was found. Previous research has shown that both mu and beta power are modulated during action observation, although they have been associated with slightly different functions (Caetano, Jousmãki, & Hari, 2007; Meyer et al., 2011; Quandt & Marshall, 2014; Schuch, Bayliss, Klein, & Tipper, 2010). Mu-band activity is suggested to be involved in translating sensory input into motor processes (Naeem et al., 2012; Pineda, 2005; Vanderwert et al., 2013), which matches with its more posterior localization over sensorimotor regions of the brain (Ritter, Moosmann, & Villringer, 2009). In contrast, the location of beta oscillatory activity is typically more anterior and it is associated with activity in the motor and premotor cortex (Ritter et al., 2009). It has been suggested that both mu- and beta-band oscillations are involved in action predictions (Southgate et al., 2009; Stapel et al., 2010), while beta-band activity is associated specifically with prediction updating and error monitoring (Arnal, Wyart, & Giraud, 2011; Koelewijn, van Schie, Bekkering, Oostenveld, & Jensen, 2008). Exactly these processes – monitoring others' actions and integrating information in order to update action predictions – are important during cooperation (Kourtis et al., 2013; Sebanz et al., 2006). Updating action predictions and monitoring were essential for the current peer cooperation task. Predicting which tube the partner would choose, monitoring the partner's behavior to check whether the prediction was correct, and updating one's predictions were necessary to succeed on the task. This might also explain why a relation between cooperation performance and oscillatory modulation was observed in the beta-band. Still, the exact functional differences between mu- and beta-band oscillations and their respective roles during action observation have to be determined in future research.

For both mu- and beta-power, we observed that power values were higher during action observation than baseline indicating enhancement rather than suppression. At first sight, this is surprising since previous research suggests that suppression of mu- and beta-power indicate increased involvement of the motor system (Marshall & Meltzoff, 2011; Rizzolatti & Fogassi, 2014). However, several recent studies also found that power in these frequency bands is not significantly suppressed during action observation (Cannon et al., 2016; Nyström, 2008; Perry & Bentin, 2010) or even enhanced (Marshall, Saby, & Meltzoff, 2013). Although in our study the neural response showed an unexpected directionality with regard to baseline, we are confident that the mu- and beta-band activity reflects a response of the motor system for two reasons. First, the effect was relatively confined to electrode sites overlaying over motor areas (C3, C4), which suggests a modulation of the motor system. Second, children were asked to sit motionless and watch three repetitions of each action video on the screen before they were allowed to respond. Thus, children likely tried to actively inhibit an overt motor response during the action observation, and this was associated with an increase in beta-power (Gilbertson, Doyle, Di Lazzaro, Cioni, & Brown, 2005). Notably, this motor inhibition did not affect the direction of the relation we found. That is, less beta power with respect to baseline (indicating relatively more motor activity) was related to more success during peer cooperation. Although children thus likely suppressed their motor activity in general to sit as motionless as possible, interindividual differences with respect to how sensitive their motor system was to action observation were still related to their cooperation behavior.

Our results suggest that interindividual differences in neural mirroring are related to successful cooperation. Yet, the causal direction underlying this relation remains an open question. Better interpersonal coordination likely is the result of higher general levels of neural mirroring. Previous research has shown that neural mirroring supports prediction (e.g., Southgate et al., 2009; Stapel et al., 2010) and monitoring of others' actions (Becchio et al., 2012; Bekkering et al., 2009) as we can use our own action system to predict the actions of a partner (Kilner et al., 2007). Enhanced prediction and monitoring, in turn, might help us prepare for and execute our own actions accordingly (Kourtis et al., 2013; Sebanz et al., 2006). Based on this reasoning, individuals with higher levels of neural mirroring might be better at coordinating their actions with others. However, neural mirroring and cooperation might also both be the result of a third factor, such as social motivation. Children differ in their motivation to be involved in social interactions (Brownell & Hazen, 1999), which could impact both their level of mirroring and their cooperation success. Neuroimaging studies in adults have shown a role of social motivation for mirroring as they found enhanced mirroring when participants were socially primed (Hogeveen & Obhi, 2012; Oberman, Pineda, & Ramachandran, 2007), and enhanced mirroring for in-group members than for out-group members (Gutsell & Inzlicht, 2010; Molenberghs, Halász, Mattingly, Vanman, & Cunningtong, 2013; Rauchbauer, Majdandžić, Hummer, Windischberger, & Lamm, 2015). Studies with adults also support the role of social motivation in interpersonal coordination: Adults with a pro-social orientation coordinated their actions better than adults with a pro-self orientation (Lumdsen, Miles, Richardson, Smith, & Macrae, 2012). Whether children's neural mirroring is really at the base of their interpersonal coordination or whether both are the result of their social motivation has to be addressed in future research.

The question arises to what extent interindividual differences in neural mirroring play a role in children's social development. Friedlmeier (2009) suggested that adapting behavior might be an indicator of social competence. In addition Cirelli, Einarson, and Trainor (2014), and Kirschner and Tomasello (2010) found more helping behavior in children after they experienced smooth interpersonal coordination. This increased prosociality could be an indicator of likeability, thereby suggesting that higher levels of mirroring result in better peer relations via successful interpersonal coordination. However, a relation between interpersonal coordination and peer preference was not present in a recent longitudinal study we conducted (Endedijk, Cillessen, Bekkering, & Hunnius, resubmitted (Chapter 5)). On the other hand, the increased helping behavior as response to interpersonal coordination also could suggest that mirroring supports estimation of the needs of peers. Baimel, Severeson, Baron, and Birch (2015) argued that coordinating interpersonally helps reasoning about others' mind, thereby fostering perspective taking and empathic concern. Although the exact social consequences of peer coordination are unclear, these lines of reasoning suggest that interindividual differences in neural mirroring may have several implications for children's social development.

In summary, our findings suggest that interindividual differences in the degree to which children mirror others' actions are closely related to how well they coordinate their own actions during cooperation with peers. To our knowledge, these findings provide the first evidence that interindividual differences in motor activation during action observation might underlie interpersonal coordination and successful social interaction.



Computerized Sociometric Assessment for Preschool Children

H. M. Endedijk
A. H. N. Cillessen

Based on:
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4

ABSTRACT

In preschool classes, sociometric peer ratings are used to measure children's peer relationships. The current study examined a computerized version of preschool sociometric ratings. The psychometric properties of computerized sociometric ratings and traditional peer ratings for preschoolers were compared. The distributions, inter-item correlations, and reliabilities of sociometric scores were comparable between the computerized assessment and traditional assessment. The computerized assessment provided additional data for further analysis of the peer evaluation process. Therefore, computerized peer ratings are a promising tool for sociometric measurement with preschool children.

INTRODUCTION

Sociometric assessment is used to study children's peer relationships at school by measuring acceptances and rejections (Bukowski, Sippola, Hoza, & Newcomb, 2000). Typically, peer nominations are used with school-age children, but for preschool-aged children sociometric ratings are often used that go back to a procedure introduced by Asher, Singleton, Tinsely, and Hymel (1979). Because sociometric methods can be used to identify children at risk, it continues to be important to develop optimal methods of sociometric assessment for widespread use in various age groups.

Among school-aged children, researchers increasingly collect sociometric nominations via computerized assessments. This is less time-consuming, costly, and error-prone than paper-and-pencil assessments and makes it easier to store data confidentially (see, e.g., van den Berg & Cillessen, 2013). Sociometric ratings with preschool children might also benefit from computerized assessment, but this is yet unknown. Therefore, the current study examined the use of a computerized sociometric ratings procedure for preschool children.

Peer nominations of most and least preferred classmates are most common in sociometric research. However, peer nominations are less reliable among preschoolers due to the instability of social structure at this age (e.g., frequent changes in friendships) (Asher et al., 1979) and due to recency effect when making peer nominations. Peer ratings are more reliable at this age, as children receive a rating from each classmate and individual perceptions do not affect total scores as much as with nominations (Asher et al., 1979; Hymel, 1983). Therefore, researchers often have used peer ratings instead of nominations with preschool children.

In the ratings procedure, preschool children are asked to indicate, for a photograph of each classmate, how much they like to play with this child on a 3-point-scale (Dorval & Bégin, 1985). There is some variation in the photographs, ranging from individual photos presented alone, to individual photos presented on a poster (board) (see Olson & Lifgren, 1988; Wasik, Wasik, & Frank, 1993; Wu, Hart, Draper, & Olsen, 2001) to class pictures (see Cillessen, 1991; Cillessen, van IJzendoorn, van Lieshout, & Hartup, 1992; Denham et al., 2003; Hall & McGregor, 2000; Sanderson & Siegal, 1995). Usually, the rating options are made concrete by letting the child put the photographs into different boxes with happy, neutral, and sad smiley-face emoticons on them (e.g., Denham et al., 2003; McCabe & Meller, 2004; Sette et al., 2013; Walker, 2009; Wu et al., 2001).

A computerized version would follow the same procedure, but instead of printed photographs and smileys, they can be presented on a computer screen. Children's peer ratings can then be recorded by clicking with the mouse on the corresponding smiley. This way of presenting stimuli and response categories could affect three elements of the sociometric method: 1) data collection, 2) organization of the data collection, and 3) data processing.

Data Collection

A first advantage of computerized data collection for preschoolers is the sequential presentation of photographs. Preschoolers are easily distracted by visual material (Ruff & Capozzoli, 2003). The visual distraction caused by seeing 30 photographs at the same time may lower the quality of their answers. On the computer, distractions are reduced, as previous and subsequent photographs are not visible.

A related issue is the distribution of photographs. Preschoolers try to distribute things evenly between options (LoBue, CNishida, Chiong, DeLoache, & Haidt, 2009; Olson & Spelke, 2008), even when attributing resources to someone they like and someone they dislike (Kenward & Dahl, 2011). This could result in an equal distribution of photographs across response categories, or a different distribution of pictures in the beginning of the sociometric assessment compared with the end. On the computer, children will be less influenced by their earlier choices, as they cannot see their previous answers.

Computerized assessment also facilitates the randomization. In a middle school sample, Poulin and Dishion (2008) found a tendency for those listed earlier to be nominated more frequently. Similar order effects may influence peer ratings on a poster (board) or class photograph, or when individual photographs are not properly randomized for each assessment. Computerized assessment makes it easy to fully randomize the order in which peers are evaluated between participants.

The final data collection advantage of computerized assessment is its suitability for young children. Most children like computers and see the computer task as a game. This helps to sustain their interest (Dorval & Bégin, 1985). Shy children who may be intimidated by an experimenter (Marks, 1987), might find it easier to answer nonverbally (on the computer) than verbally (to the experimenter). Thus, the attractiveness of a computer task and the possibility to answer via a computer may make the assessment less invasive for young children.

Organization of the Data Collection

An organizational advantage of computerized assessment is the efficiency of administration (Garb, 2007). Task preparation is faster as photographs do not have to be printed before an assessment and software can directly import digital photographs. Moreover, data processing is faster as data is stored automatically (Garb, 2007).

Computerized assessment also saves money. The high initial costs of a laptop and specialized software (Bennett, 2006) are off-set by saving the costs of printing photographs and data entry personnel. Moreover, the laptop and software can be used for multiple projects over multiple years. Therefore, computerized assessment is financially profitable especially for longitudinal or large-scale studies (Bennett, 2006).

Data Processing

Computerized assessment also has several advantages for data processing. First, data entry errors are less likely. As the data are automatically stored as they are being collected, errors as a consequence of manual data entry are eliminated (Allard, Butler, Faust, & Shea, 1995).

Automatic data processing also has an ethical advantage. In traditional assessments, researchers typically maximize the confidentiality of children's answers by replacing names with code numbers and by keeping names and codes on separate sheets. On a computer it is easy to directly save answers by codes only. Although preschool children are too young to understand confidentiality (Bell-Dolan & Wessler, 1994), for parents who are asked permission for participation it may help to know that only code numbers, and not names, are saved directly into data files.

Further, computerized assessment will offer new possibilities for the analysis of sociometric data that have not yet been considered. Computerized assessment yields the same data as traditional assessment but will also afford new analyses of response times or order effects.

Current Study

In this study, a new computerized sociometric assessment for preschoolers was compared with traditional sociometric assessment. It was examined whether computerized assessment yielded results comparable to traditional assessment. Moreover, additional analysis possibilities afforded by the computerized assessment method were explored by examining order effects.

METHOD

Participants

Schools came from a pool of 90 schools (128 classes) in the Nijmegen area (a Dutch mid-size city) in which children were tested as part of a longitudinal study. In all schools except one, preschool classes participated in computerized sociometric assessment. The exception was a school that had the policy not to work with computers in preschool classes; this class was tested with traditional sociometric assessment. Two schools that participated with some of their preschool classes were willing to enroll two extra classes in traditional assessment. This yielded traditional assessments in five classes from three schools. There was no indication that the class with the policy not to work with computers differed from the other four classes.

To compare the traditional assessment in those five classes with computerized assessment, we took two sets of five comparison classes from the 128 classes of the longitudinal study in which computerized assessment had taken place; one set of five randomly selected classes, and one set of five classes that matched the characteristics of the five traditional assessed classes. Matching was based on neighborhood, number of preschool classes in the school, and class size. Thus, the final sample for this study included children from 15 classes (five traditional assessed, five computerized random, five computerized matched) from nine schools.

Participants were 411 preschoolers aged 4 to 6 years (49.1% boys). Classes were mixed-age as children enrolled as soon as they were 4 years old and stayed until the summer in which they were 6 or would turn 6 before next Christmas.

Teachers gave active consent whereas parents gave passive consent. Teachers gave the parents of all children a letter in which the study was explained; parents could indicate if they did not want their child to participate. No parent refused participation. Teachers were offered a picture book for the participation with their class. The project was approved by the IRB.

Table 4.1 presents descriptive statistics of the classes in the three conditions. One-way ANOVAs for traditional assessed versus computerized matched classes and traditional assessed versus computerized randomly selected classes revealed no differences in the number of participating children, class size, or percentage of boys (all *p*s $>.05$).

Table 4.1. Average Number of Participants, Class Size, and Percentage of Boys in the Traditional, Computerized Matched and Computerized Random Classes

		Participants		Class Size		Percentage Boys	
	N	*M*	*SD*	*M*	*SD*	*M*	*SD*
Traditional	136	27.20	3.96	29.20	3.90	47.16	4.88
Computerized matched	142	28.40	4.28	29.40	3.13	51.40	3.88
Computerized random	133	26.80	3.03	28.00	3.32	48.16	12.11
Total	411	27.47	3.58	28.87	3.27	48.91	7.52

Sociometric Assessment

Sociometric ratings used a 3-point scale with class as the reference group, rating both same-sex and other-sex peers. All conditions used the same sociometric question: "Do you like to play with X (child's name), not like to play with X, or sometimes like and sometimes not like to play with X?" Each child was asked this question by the experimenter while facing a photograph of its classmate. In the beginning the question was supported by pointing to corresponding smileys (happy, neutral, and sad).

In all conditions, the session started with a picture of the child herself while explaining that we would like to know with which classmates she likes to play. Then two practice trials started with a picture of a ball and a toy train in random order to make sure the child understood the procedure and to explain the task in more detail if needed. After the practice trials the experiment started with sequential pictures of classmates in random order.

In the computerized assessment children responded to the questions by clicking on the corresponding smileys with the computer mouse (occasionally supported by the experimenter). In the traditional assessment children responded to the questions by putting the photographs in one of three boxes with smileys on them. To make sure that children recognized their classmate on the picture, children were asked to mention the name of the classmate. If a child did not know the name or gave a wrong name, the experimenter suggested the correct name. If the child still did not know or recognize the classmate the rating of the classmate was coded as missing.

The sociometric assessment lasted approximately 5 minutes in both conditions and took place in a separate quiet room in the school. The experimenter, unfamiliar to the child, was present the entire time.

Sociometric Scores

Three sets of variables were computed from the raw ratings in exactly the same way for the computerized and traditional assessed data. First, the numbers of liked, disliked, and neutral ratings received were counted for each child. To control for differences in class size, these numbers were transformed into percentage scores by dividing them by the total number of raters in the class. In addition, the percentages of liked and disliked ratings were transformed to z scores within classes, so that social preference, social impact, and sociometric status groups could be determined following Coie, Dodge and Coppotelli (1982). This is a regular procedure based on nominations, but is also suitable for ratings (Maassen, Akkermans, & van der Linden, 1996). Social preference was computed as the difference between the standardized liked and disliked scores, and again standardizing the difference within classes. Social impact was computed as the sum of the standardized liked and disliked scores, again standardized within classes. Finally, using the standardized liked, disliked, preference, and impact scores, each child was assigned to one of the five sociometric status groups accepted, rejected, neglected, controversial, and average following Coie et al.'s criteria. Thus, the sociometric assessment yielded the variables: 1) percentage of liked, disliked, and neutral scores, 2) social preference and social impact scores, and 3) status groups.

RESULTS

Descriptive Statistics and Correlations

Intraclass correlations (ICCs) were calculated to determine how much of the variance in the liked, neutral, and disliked percentages was due to class differences in each condition. The ICC was higher than .05 for most variables, indicating that children's scores were more comparable within classes than between classes. Therefore, dif-

Table 4.2. Percentages Liked, Neutral and Disliked Scores in the Traditional, Computerized Matched, and Computerized Random Classes

	Traditional		Computerized Matched		Computerized Random	
	M	*SD*	*M*	*SD*	*M*	*SD*
Liked	47.58	13.41	40.39	13.61	46.51	18.28
Neutral	25.33	8.13	26.52	10.56	23.38	8.08
Disliked	27.19	13.60	33.16	13.96	30.10	17.68

ferences between conditions were tested as Multilevel Linear Mixed Models with random intercepts with children at Level 1 and classes at Level 2.

Table 4.2 presents the means and standard deviations of the liked, neutral, and disliked percentages. The multilevel analyses indicated no differences between traditional and computerized matched groups on the liked, neutral, or disliked percentages, $F(1, 7.82) = 2.35$, $p = .16$, $F(1, 7.91) = .01$, $p = .93$, and $F(1, 10.22) = 2.77$, $p = .13$, respectively. There were also no differences between the traditional and computerized random groups, $F(1, 7.98) = .06$, $p = .82$, $F(1, 8.77) = 2.61$, $p = .14$, and $F(1, 8.01) = .47$, $p = .51$, respectively. Thus, there were no differences in the percentages of liked, neutral, and disliked ratings given in the traditional and computerized assessments.

Fisher's *r*-to-*Z* transformations tested whether the correlations among the liked, neutral and disliked percentages and social preference and impact differed between conditions (Table 4.3). Only the correlations between liked and disliked ($Z = 2.16$,

Table 4.3. Correlations Among Sociometric Scores in Traditional, Computerized Matched, and Computerized Random Classes

	Liked	Neutral	Disliked	Preference	Impact
Traditional					
Liked	-				
Neutral	-.29**	-			
Disliked	**-.81****	-.32**	-		
Preference	.87**	-.05	-.83**	-	
Impact	.30**	**-.94****	.28**	.00	-
Matched					
Liked	-				
Neutral	-.36**	-			
Disliked	**-.70****	-.41**	-		
Preference	.84**	.06	-.86**	-	
Impact	.27**	**-.72****	.28**	.00	-
Random					
Liked	-				
Neutral	-.29**	-			
Disliked	**-.90****	-.16	-		
Preference	.92**	-.13	-.89**	-	
Impact	.22**	-.93**	.21**	.00	-

Note. Correlations that are bold were significantly different ($p < .05$) between computerized matched or random classes and traditional classes.

* $p < .05$, ** $p < .01$.

4

Table 4.4. Distribution of Status Groups in the Traditional, Computerized Matched, and Computerized Random Classes

	Traditional		Computerized Matched		Computerized Random	
	N	%	*N*	%	*N*	%
Accepted	13	9.56	21	14.79	20	15.04
Rejected	23	16.91	22	15.49	24	18.05
Neglected	10	7.35	15	10.56	5	3.76
Controversial	8	5.88	5	3.52	1	.75
Average	82	60.29	79	55.63	83	62.41
Total	136	100.00	142	100.00	133	100.00

Table 4.5. Internal Consistency (Kuder-Richardson Formula 20, KR-20) and Interrater Reliability (Fleiss Kappa) in Traditional, Computerized Matched, and Computerized Random Classes

	Traditional		Computerized Matched		Computerized Random	
	M	*SD*	*M*	*SD*	*M*	*SD*
KR-20						
Liked	.75	.10	.80	.07	.75	.11
Disliked	.76	.11	.81	.04	.79	.05
Fleiss Kappa						
Liked	**.04**	.01	.03	.03	**.09**	.04
Disliked	.06	.02	.05	.05	.11	.07

Note. Values that are bold were significantly different ($p < .05$) between computerized matched or random classes and traditional classes.

$p = .03$) and neutral and impact ($Z = 6.99$, $p < .001$) differed between the traditional and computerized matched classes. In both cases the correlation was more strongly negative in the traditional than in the computerized matched classes. For the traditional versus computerized random classes only the correlation between liked and disliked ($Z = 2.64$, $p = .01$) differed. This correlation was stronger in computerized random classes than traditional classes, which contradicts the finding for the computerized matched classes. However, the general pattern of correlations did not differ between the traditional and computerized assessments.

The distribution of status groups (Table 4.4) was consistent with the distribution reported for other studies in preschool classes (see Terry & Coie, 1991). Multilevel analyses indicated that the distribution of status groups did not differ between traditional and computerized matched classes, $F(1, 276) = 1.25$, $p = .26$, or between traditional and computerized random classes, $F(1, 267) = .46$, $p = .50$.

Internal Consistency

Kuder-Richardson Formula 20 (KR-20) was used to compare the internal consistency of sociometric scores between conditions. KR-20 is identical to Cronbach's a, but for dichotomous data (Kuder & Richardson, 1937). For each class, liked ratings were converted to a 0–1 matrix with raters in rows and ratees in columns. When a child rated a peer as liked, the cell indicated a 1, otherwise a 0. If a child rated no one or everyone as liked, the child's responses were coded as missing. A disliked matrix was created in the same way. KR-20 was then computed with the raters as participants and the ratees as "items".

Internal consistency was generally high (Table 4.5), indicating that the construct scores were homogeneous. One-way ANOVAs yielded no differences in the internal consistency of liked scores between the traditional and computerized matched groups, $F(1, 9) = .76$, $p = .41$, $\eta^2 = .08$, or between the traditional and computerized random groups, $F(1, 9) < .01$, $p = .97$, $\eta^2 < .01$. The same was the case for disliked scores, $F(1, 9) = .86$, $p = .38$, $\eta^2 = .10$, and $F(1, 9) = .39$, $p = .55$, $\eta^2 = .04$, respectively.

Interrater Reliability

Fleiss Kappa's were calculated for liked and disliked scores, to test whether interrater reliability (agreement between children) differed between conditions. Fleiss Kappa is similar to Cohen's Kappa, but designed to measure agreement between more than two raters (Fleiss, 1971). The same dichotomization steps were used as for calculating KR-20, but the rows and columns were reversed so that Kappa between the columns (variables) indicated interrater agreement.

Interrater reliabilities were generally low (Table 4.5), indicating that children within a class did not agree on whom they liked or disliked. One-way ANOVAs showed differences in liked scores between the traditional and computerized random groups, $F(1, 9) = 9.53$, $p = .02$, $\eta^2 = .57$, but not between the traditional and matched groups, $F(1, 9) = .87$, $p = .38$, $\eta^2 < .001$. Thus, children agreed more on whom they liked in the computerized random classes than in the traditional assessed classes. The reliabilities of the disliked scores in the traditional assessed classes did not differ from the computerized matched classes, $F(1, 9) = .33$, $p = .58$, $\eta^2 < .001$, or computerized random classes, $F(1, 9) = 1.88$, $p = .21$, $\eta^2 = .19$.

Exploration of Order Effects in Computerized Assessment

To examine order effects in the computerized assessment, liked, neutral, and disliked raw scores were compared between the first half of the photographs and the second half of the photographs using paired samples *t* tests. The number of neutral and disliked scores did not differ between the first and second half of the experiment, $t(275) = 1.32$, $p = .19$, $d = .08$, and $t(275) = 1.20$, $p = .23$, $d = .07$, respectively. There was a small effect for liked scores; children attributed more positive scores to classmates during the second half of the experiment than during the first half, $t(275) = 2.24$, $p = .03$, $d = .13$.

DISCUSSION

The goal of this study was to compare traditional sociometric ratings for preschool children with computerized ratings. Both methods yielded comparable distributions of ratings and status groups, and only small differences in correlations among sociometric scores. There were no differences in internal consistency and only small differences in interrater reliability. Therefore, the computerized method yielded comparable results as the traditional method.

The comparability of the psychometric properties between methods indicates that the computerized assessment is reliable and valid for measuring continuous and categorical sociometric scores. The internal consistencies were high; the ratings measured homogeneous constructs. Moreover, interrater reliabilities were low, implying that differences in children's opinions about their peers were detected. Thus, even among young children sociometric ratings are a valuable tool to measure social positions in classes both with traditional and computerized methods.

Comparisons of the traditional assessment with the two computerized conditions in terms of correlations and interrater reliabilities occasionally pointed in opposite directions, although differences were small. This could be due to differences in class size between conditions, as computerized random classes were somewhat smaller than computerized matched classes (although not significant). As children in small classes interact more with each other (NICHD Early Child Care Research Network, 2004a), they may have formed clearer opinions about one another. This may have resulted in higher consistency of scores resulting in higher interrater reliabilities and correlations. As the computerized random condition tended to be smaller than the matched condition, this could explain its somewhat higher correlations and reliabilities.

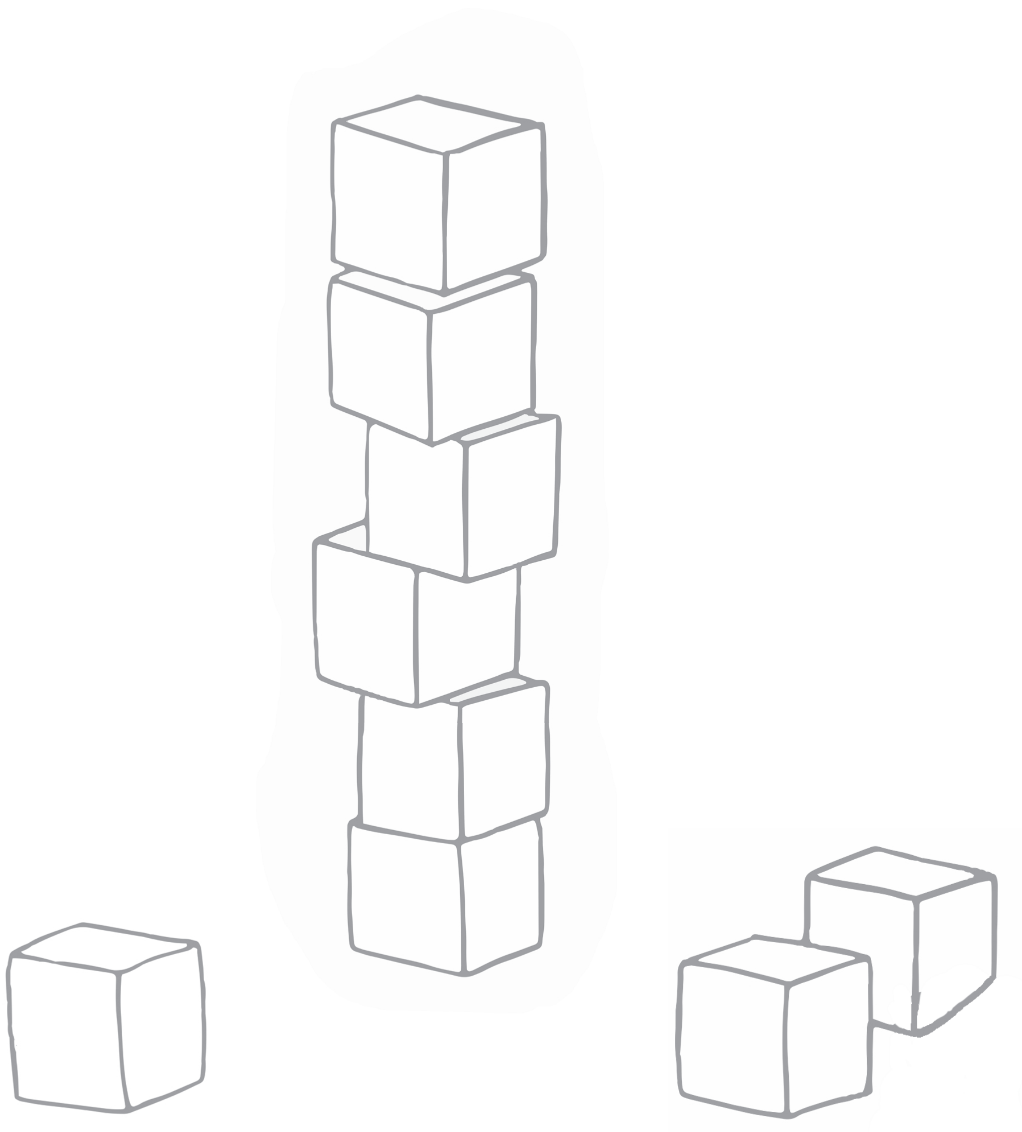
The analysis of order effects for the computerized assessment showed small differences in the number of liked ratings. Children gave more liked ratings to classmates during the second half of the experiment than during the first half. Although the effect was small, it emphasizes the need for proper randomization to make sure that children are not systematically rated in the beginning or at the end. A more extensive analysis of computerized assessment in future studies, could further clarify preschoolers' response tendencies and the way they rate each other.

As traditional and computerized assessment yield comparable results, it is promising to use computerized ratings with preschoolers given their advantages. The only disadvantage during testing appeared to be motor control, as some children had some problems handling the mouse. After a quick demonstration all children were able to use it, but some were slow or preferred experimenter assistance. Future assessments may use a touch screen instead of a mouse as already 3-year-old children appear to handle a touch screen during assessment very well (Meyer, Bekkering, Janssen, de Bruijn, & Hunnius, 2014).

The current project made general comparisons between both methods. However, a number of additional data collection options may be facilitated by computerized assessment. First, computerized assessment might make it easier for children to rate specific subgroups of peers, rather than the entire class. Second, in past research with preschoolers, paired comparisons yielded highly reliable judgments, but are very time-consuming to conduct (cf. Cillessen, 2009). Implemented on the computer, however, they may become feasible again. Third, computerized assessment might make it possible to conduct sociometric assessment with young children in small groups, rather than individually only. Fourth, computerized assessment might be suitable for younger children as comprehension could be increased with interactive smiles or videos instead of static smiles. Such additional possibilities of computerized assessment with preschoolers are highly worthwhile to examine further.

The present study had some limitations. First, the sample of schools assessed with the traditional peer ratings was small. This could have resulted in undetected small effects. Second, a completely blind assignment of schools and classes to conditions would have been better, although we have no indications that classes or schools differed from each other. Third, we could not compare the stability of computerized and traditional assessments as children were measured once. Although no differences in temporal stability are expected, it would be a central point for future studies that use computerized assessment. Moreover, it would be interesting to study different preschool ages in this respect, as traditional ratings by older children are more reliable and stable (Dorval & Bégin, 1985).

In conclusion, computerized peer ratings have many advantages and yield data of similar quality to traditional assessments. Thus, this study extends the advantage of computerized assessment to sociometric ratings with preschool children. Although we cannot generalize to peer ratings with multiple answer options (see Cassidy & Asher, 1992; Criss, Pettit, Bates, Dodge, & Lapp, 2002; Keiley, Bates, Dodge, & Pettit, 2000), or other items such as friendship (see Goldstein, English, Shafer, & Kaczmarek, 1997; Howes, Rubin, Ross, & French, 1988) or likeability (e.g., Criss et al., 2002; Keiley et al., 2000), we expect few differences with such small changes. Moreover, computerized assessment provides additional data analysis possibilities, and there are possibilities for further improvement in future research. Nevertheless, computerized peer ratings seem promising for sociometric assessment with preschool children.



Toddlers’ Peer Interaction Predicts Their Peer Preference at School Age

H. M. Endedijk
A. H. N. Cillessen
H. Bekkering
S. Hunnius

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Developmental Psychology (resubmitted).

5

ABSTRACT

Children who are more proficient in their interactions with peers tend to be more preferred. To date, the development of peer interaction has largely been studied within two lines of research, one focusing on the behaviors displayed during interaction and the other examining the level of action coordination. There are indications that both aspects of peer interaction are relevant for children's peer status, but it is unclear whether both aspects of children's interaction skills in early social development predict their later social position at school. In this study, the coordination proficiency and interaction quality of 181 children were observed longitudinally from 2 to 4 years of age. Results demonstrated that more affiliative and fewer antagonistic behaviors at age 2 predicted likeability among school peers at age 4, while there was no indication of a relation between early action coordination and later peer status. The findings shine new light on the earliest foundation of children's peer evaluations.

INTRODUCTION

From the end of the first year of life, children interact with peers around toys on a regular basis (Eckerman et al., 1975). They do so with affiliative behaviors such as when offering toys to each other, but also antagonistic behaviors such as claiming and taking away toys. By the end of the second year of life, toddlers begin to cooperate with each other, as their play activities often unfold around a common goal (Brownell, 2011).

To date, peer interaction has been studied within two lines of research: one focusing on the interaction quality and affiliative and antagonistic behaviors (see Vaughn & Santos, 2009, for a review) and the other one examining the cognitive processes of action coordination during peer interaction (see Brownell, 2011, for a review). Both research lines have demonstrated that there are large interindividual differences in children's peer interaction (e.g., Eckerman & Peterman, 2004; Endedijk, Cillessen, et al., 2015 (Chapter 2)). Studying these interindividual differences can be informative for understanding children's peer relationships, as children are sensitive to how their peers interact with them (e.g., Kleinspehn, 2008; Sette et al., 2013).

For example, if an infant offers an object, this results in a response by the peer most of the time, while trying to touch or take a toy away from a peer resulted in a response only occasionally (Williams et al., 2010). Over the preschool period, affiliative behaviors, such as sharing, helping and comforting, become more frequent (Rubin et al., 2006; Zahn-Waxler & Smith, 1992), while antagonistic behaviors, such as aggression, decline after the age of 3 (Dodge et al., 2006; NICHD Early Child Care Research Network, 2004b).

There is a long history of research showing that (pre)school-aged children who display more affiliative and less antagonistic behaviors are better liked by peers and experience rejection less often (e.g., Santos et al., 2013; Sette et al., 2013; Vaughn et al., 2003; Walker, 2009). However, existing studies investigated the relation between the quality of peer interaction and children's peer relations concurrently (e.g., Santos et al., 2013; Sette et al., 2013; Vaughn et al., 2003; Walker, 2009), or examined their longitudinal relation after children already had entered the peer group (Denham & Holt, 1993; Ladd, Price, & Hart, 1988). This leaves unclear whether children's interaction quality is a consequence of their social position in the group or predicted their peer evaluations. However, Dodge (1983) observed the development of sociometric status in newly assembled play groups of second-grade boys for 2 weeks. The findings demonstrate that in school-aged children, children's interaction quality predicts their social position as boys who showed frequent antagonistic behaviors became rejected or neglected over time.

To date, only two studies have explored whether the quality of the earliest peer interactions in toddlerhood predict children's later peer relations. Keane and Calkins (2004) followed children from 2 to 5 years of age, but did not find indications of a predictive relation. Friedlmeier's (2009) study found inconsistent results: a positive relation between toddlers' interaction quality and their later peer preference was found for a playgroup of six children who were 10 to 22 months old during the first assessment with a social evaluation 20 months later, but not for a playgroup of seven 30- to 42-month-olds with a social evaluation 12 months later. It is thus still unclear whether there is a predictive relation between the quality of peer interaction in early childhood and children's later social evaluation.

Interindividual differences in peer interaction can also be studied by examining the degree to which children adapt their actions to each other. In order to reach a common goal, children have to coordinate their actions, for instance by timing and sequencing them in relation to a partner's actions (Brownell & Carriger, 1990; Brownell et al., 2006). Children begin to show coordinated activity with peers during toddlerhood (Ashley & Tomasello, 1998; Brownell, 2011; Meyer et al., 2010), with 18- to 19-month-old infants incidentally coordinating their actions by, for example, pausing their own actions so that a peer can retrieve a toy or by synchronously pulling a handle to elicit a salient action effect (Brownell & Carriger, 1990; Brownell et al., 2006). During the third year of life, children become increasingly responsive to a peer's actions (Brownell et al., 2006) and more proficient at complex cooperation tasks such as those requiring complementary actions (Asher et al., 1979; Fletcher et al., 2012). Action coordination continues to develop throughout childhood, as children become faster and more consistent in their coordination performance (Ashley & Tomasello, 1998; Steinwender et al., 2010).

Being proficient at action coordination has a crucial impact on social relations, as has been shown in many adult studies. After coordinating their actions in a movement coordination task, such as finger tapping or moving to music, adults judged each other more favorably when the coupling has been stronger (Demos et al., 2012; Hove & Risen, 2009). Also, when adults observed others while not participating in the interaction themselves, they report higher levels of rapport for pairs with higher levels of action coordination during walking or hand waving (Lakens & Stel, 2011; Miles et al., 2009).

Such a social effect of action coordination on liking may also be present earlier in life. School-aged children rated a play partner more positively when their actions during a joint drumming task were well-coordinated (Kleinspehn, 2008). Moreover, 5-year-olds preferred a hand puppet with whom they previously had coordinated their actions in a cooperation task over another hand puppet (Plötner et al., 2015). Even at 12 months, infants preferred a teddy bear that was rocked in a chair to the same rhythm as them over a bear that was rocked to a different rhythm (Tunçgenç et al., 2015). This suggests that action coordination also has an impact on children's social evaluations. However, to date there are no studies of the role of action coordination among peers in social evaluations in early childhood.

In sum, previous research suggests that both, successful action coordination and interaction quality, have an impact on children's social evaluation. Examining whether children's skills at the very beginning of social development might predict their likeability among peers later in school is extremely relevant. Once established, peer status is stable across childhood (Quinn & Hennessy, 2010) and has consequences for academic adjustment (e.g., Morris et al., 2013; Wilson et al., 2011) and the development of behavior problems (e.g., Berdan et al., 2008; Ladd, 2006; Ladd & Troop-Gordon, 2003).

In this study, we followed children from 2 years of age until they were 4 years old and examined both their action coordination performance and the quality of their interactions during cooperation with a peer at three points in time. After children entered school, we assessed their peer preference and examined the predictive relations between children's early action coordination and interaction quality and later preference among their peers in the first year of school. We hypothesized that toddlers' action coordination and their interaction quality would be fundamental aspects of successful early social interaction and therefore that both would uniquely predict children's later evaluation by peers.

METHOD

Participants

Participants were 181 children, who were tested at 28 months (M = 27.97, SD = .31), 36 months (M = 35.93, SD = .31), 44 months (M = 43.85, SD = .32), and 52 months (M = 51.67, SD = 1.17) of age. Dropout rates were low: The sample consisted of 180 children at 28 months, 164 at 36 months, 160 at 44 months, and 167 at 52 months. Of all children, 5

48% were boys. Children were selected from a database of families in the Nijmegen area (a Dutch city with approximately 165,000 inhabitants) who were willing to participate with their child in research. All children were healthy and showed no indications of atypical development. The study was approved by the Ethics Committee of the university's Faculty of Social Sciences.

At 28, 36, and 44 months, children were invited to the lab for a play session and randomly paired with an unfamiliar same-sex peer (also of the longitudinal sample), who was different for each play session. All children spoke Dutch and came from mixed socioeconomic backgrounds. Parents were informed of the topic and procedures of the study and signed a consent form. Children who were unable to participate in a play session at 36 or 44 months due to scheduling problems were allowed to continue participation in the study. Dyads were excluded from the analyses if one or both children did not engage at all in the cooperation task (12 dyads at 28 months; 8 dyads at 36 months; 5 dyads at 44 months).

At 52 months, sociometric data were collected in the longitudinal children's classrooms. Of the 90 different schools in which children were enrolled, 88 agreed to participate, of which one could not be included due to scheduling problems, yielding 87 schools with 124 classes. The parents of all children in these classes (longitudinal and classmates) received a letter carefully explaining the study and asking permission for a 5-minute sociometric interview with their child at school. Fourteen parents did not want their child to participate, yielding a sample of 3104 4-to-6 year-old children (51% boys; M = 25 per class, SD = 5). Classes were mixed in age, because in the Netherlands children begin school on their 4th birthday and stay in the same class until the summer of the year they turn 6.

Procedure

The lab play sessions at 28, 36, and 44 months started with 10 to 30 minutes of free play during which children could familiarize themselves with each other, the experimenters, and the novel environment. This acquaintance phase was followed by a 5-minute cooperation task, followed by another 5-minute task for a different study. Parents were asked to minimize their own interactions with the children. If a child was clinging to the parent, the parent was asked to respond in ways to stimulate play without helping with the task. Overall, sessions lasted around 45 minutes. Children received either a book or €10 "for their piggy bank" as a thank you for participation. The complete session was videotaped from two angles. One 28-month-old dyad had to be excluded due to missing video recordings.

For the sociometric assessment at 52 months, children were interviewed individually in a quiet room at school. The interview lasted approximately five minutes and the experimenter, unfamiliar to the child, was present all the time. Teachers were offered a picture book for their class as a thank you for participation.

Cooperation Task

The cooperation task was based on Warneken et al.'s (2006) double-tube task. The setup consisted of two 1-meter tubes mounted in parallel on a box with a 45-degree incline (Figure 5.1). The two children were shown a Playmobil figure (Geobra Brandstätter GmbH & Co.KG, Zirndorf, Germany) in a swimsuit and a small swimming pool. They were instructed that the figure wanted to go through the sliding tube into the pool. The tubes were too long for one child to both hold the pool and insert the figure into the tube at the same time. Therefore, the two children had to cooperate to perform the task. A detailed description of the task can be found in Endedijk, Cillessen, et al. (2015 (Chapter 2)).

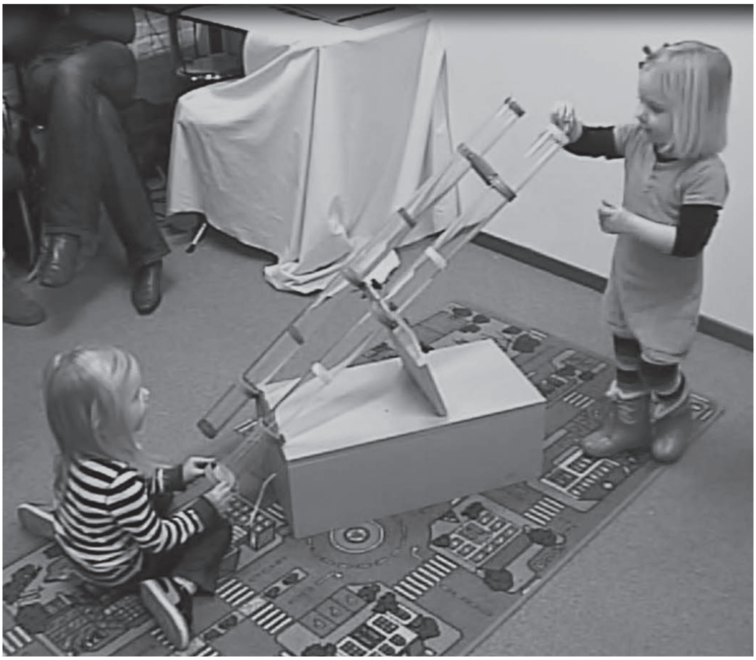


Figure 5.1. Children coordinating their actions during the cooperation task.

Children's task actions of choosing for one of the tubes with the figure or pool, and sliding the figure through the tubes were coded off-line from the video recordings. To measure whether children coordinated their actions to each other, we coded the task actions that came after the partner had chosen one of the tubes with the figure or the pool. Actions were coded as "coordinated" if: (1) the child approached the same tube with the figure as the partner held the pool under, (2) the child approached the same tube with the pool as the partner held the figure above, or (3) the child let the figure slide at a moment when the swimming pool was below the tube. Actions were coded as "uncoordinated" if: (1 & 2) the child choose a different tube as the partner (with either figure or pool), or (3) the child let the figure slide at a moment when the pool was not below the tube. This last uncoordinated action could be due to sliding the figure through the 'wrong' tube or due to sliding the figure at a moment when the partner was not holding the pool below one of the tubes. The recordings of 20% of the dyads at each time point were coded by two observers. Cohen's Kappa (*K*) was .84 on average (range .42–1). Two scores were calculated for each child: the frequency of coordinated actions per minute and the frequency of uncoordinated actions per minute.

Interaction quality was coded for each child using a coding scheme based on Hunnius et al. (2009). Behaviors were divided into the categories *affiliative* and *antagonistic*. Affiliative behaviors were sharing, helping, directing, asking for material/procedure, asking for help, agreeing, and giving a positive response. Antagonistic behaviors were taking away, competing, claiming/hindering, protesting, aggression, and neglecting (see Endedijk, Cillessen, et al., 2015 (Chapter 2), for definitions and details of the coding scheme). The first author trained eight independent coders. They were regularly monitored, as one in six videos was double-coded by the trainer. Coders had to have more than 70% agreement within a 3-second interval to allow them to continue. Two coders who failed this criterion in the beginning received additional training. Cohen's Kappa was .75 on average (range .58 - .93). Based on the coded behaviors, two scores were calculated for each child: the frequency of affiliative behaviors per minute and the frequency of antagonistic behaviors per minute.

Sociometric Assessment

Children rated all classmates on a 3-point scale. For each classmate they were asked: "Do you like to play with X (child's name), do you not like to play with X, or do you sometimes like and sometimes not like to play with X?" The experimenter presented a photograph of the classmate on a computer screen with three smiley faces below (happy, neutral, and sad) for the three scale options. Children rated each classmate by clicking on one of the smiley faces (see Endedijk & Cillessen, 2015 (Chapter 4), for a detailed description of the procedure). The pictures of the classmates were presented in random order. One school had the policy not to work with computers in the classroom. Therefore, for one class, the procedure was exactly the same except that pictures were printed and sorted into plastic boxes with the smiley faces on them. Earlier research showed no difference in results obtained via this procedure and the computerized procedure (Endedijk & Cillessen, 2015 (Chapter 4)).

Based on the raw numbers of liked, disliked, and neutral choices received, children's social preference score was calculated following Coie et al. (1982). The percentages of liked and disliked choices were transformed into *z*-scores within classes to control for differences in class size. Social preference was computed as the difference between the standardized liked and disliked scores, and again standardized within classes.

Missing Data

As children could only receive scores for the cooperation task when both dyad members were involved in the task, missing data occurred for 17% of all scores, with 39% of the participants missing data for at least one time point. Little's (1988) Missing Completely At Random (MCAR) test yielded a nonsignificant χ^2 (χ^2/df) of 70.81, indicating that there were no systematic differences between participants with complete data and participants with partially missing data.

RESULTS

Preliminary Analyses

A mixed-model analysis showed that children performed more coordinated actions as they grew older, $F(2, 250.87) = 157.08$, $p < .001$, $r = .62$, with significant differences between all ages (see Table 5.1). Also, the frequency of uncoordinated actions differed between ages, $F(2, 288.70) = 5.32$, $p = .005$, $r = .13$, with a lower frequency at 36 months than at 28 and 44 months. Moreover, children showed a higher frequency of affiliative behaviors, $F(2, 290.23) = 30.24$, $p < .001$, $r = .31$, and a lower frequency of antagonistic behaviors as they grew older, $F(2, 338.83) = 9.97$, $p < .001$, $r = .17$, with significant differences between 28 months and the older two ages.

Table 5.1. Descriptive Statistics, Intraclass Correlations (ICC), Correlations Between Measures, and Correlations Across Age for the Frequency of Coordinated and Uncoordinated Actions and Frequency of Affiliative and Antagonistic Behaviors at 28, 36 and 44 Months

	Frequency per minute		Partner dependence	Correlation same age, other measure			Correlation other age, same measure	
	M	*SD*	ICC	Coordinated actions	Uncoordinated actions	Affiliative behaviors	28 months	36 months
Coordinated actions								
28 months	.62	.89	.74***	-	-	-	-	-
36 months	2.33	1.22	.53**	-	-	-	-.06	-
44 months	2.82	1.67	.65***	-	-	-	.01	-.03
Uncoordinated actions								
28 months	1.32	1.04	-1.70	-.11	-	-	-	-
36 months	1.05	.78	-.68	.02	-	-	.08	-
44 months	1.35	1.07	.05	.08	-	-	-.02	.17^t
Affiliative behaviors								
28 months	1.06	1.13	.38*	.29***	.02	-	-	-
36 months	2.25	2.00	.31^t	.28**	.05	-	.07	-
44 months	2.18	2.05	.30^t	.19*	.02	-	.04	.12
Antagonistic behaviors								
28 months	1.66	1.62	.71***	-.02	.16^t	.07	-	-
36 months	1.25	1.18	.61***	.14	.00	.41 ***	-.04	-
44 months	.99	.98	.58***	.05	.05	.42 ***	.03	.14

Note. * $p < .05$, ** $p < .01$, *** $p < .001$, ^{t} $p < .10$.

As children performed the task in dyads, we examined the degree to which the performance of the dyad members was interrelated by means of intraclass correlations (ICC). The ICCs indicated that children's interaction quality (both affiliative and antagonistic) and their coordinated actions highly depended on each other at all three ages, but not their uncoordinated actions (see Table 5.1).

Correlations were computed to determine whether the relations between variables were weak enough to include them in one regression analysis. The variables measured separate constructs, as they were not strongly correlated (see Table 5.1). Coordinated actions had a low positive correlation with affiliative behaviors indicating that children who showed more affiliative behaviors also coordinated their actions more frequently. Affiliative behaviors were moderately positively correlated with antagonistic behaviors at 36 and 44 months, indicating that children showing affiliative behaviors more frequently also displayed antagonistic behaviors more frequently. The measures were not significantly correlated across ages, indicating that there was little stability over time.

Relation Between Peer Interaction and Peer Preference

A regression analysis was run to test whether the frequency of coordinated and uncoordinated actions and affiliative and antagonistic behaviors predicted children's later peer preference[1]. The model was significant, $F(12, 94) = 1.90$, $p = .04$, $R^2 = .20$. In this model, the affiliative behaviors at 44 months positively predicted children's peer preference in school (see Table 5.2). There was also a marginally significant relation between affiliative behaviors at 28 months and later peer preference. Antagonistic behaviors at 44 months were negatively related to children's later peer preference, and antagonistic behaviors at 28 months were marginally related to children's peer preference. Thus, children who interacted more positively during cooperation with a peer by showing more affiliative behaviors and fewer antagonistic behaviors were more preferred by their later classmates, and this prediction already held for behaviors observed at 28 months. At 44 months, the frequency of coordinated actions marginally and negatively predicted peer preference indicating that children who showed more coordinated actions at 44 months tended to be less preferred by their later classmates. There were no other relations between the frequency of (un) coordinated actions and later peer preference.

1 Given the measurement of peer preference at an individual level and a different interaction partner at each time point, it was not possible to take into account the dyadic dependency of children's behavior in the main analyses.

Table 5.2. Regression Results Predicting Peer Preference at 52 Months from the Frequencies of Coordinated and Uncoordinated Actions and Affiliative and Antagonistic Behaviors at 28, 36, and 44 Months

	β	*p*
Coordination performance		
Coordinated actions		
28 months	-.09	.39
36 months	-.05	.63
44 months	**-.18**	**.07**
Uncoordinated actions		
28 months	-.14	.18
36 months	.04	.72
44 months	-.10	.33
Interaction quality		
Affiliative behaviors		
28 months	**.20**	**.06**
36 months	-.12	.28
44 months	**.24**	**.03**
Antagonistic behaviors		
28 months	**-.18**	**.07**
36 months	-.04	.72
44 months	**-.26**	**.02**

Note. Significant ($p < .05$) or marginally significant ($p < .10$) predictors are in bold.

DISCUSSION

We investigated the relation between peer interaction in toddlerhood and later peer preference. Both children's ability to coordinate actions and their interaction quality during peer play were assessed longitudinally at ages 28, 36, and 44 months. At 52 months, children's preference among their classroom peers was examined. Results revealed that children who showed more affiliative and fewer antagonistic behaviors during toddlerhood were more preferred by their peers at 4 years of age when they were in school. These results are consistent with earlier findings of an association between peer interaction quality and peer evaluation in (pre)school-aged children (e.g., Rubin, Daniels-Beirness, & Hayvren, 1982; Sette et al., 2013; Vaughn et al., 2003). Importantly, they show that children's peer status in school can be predicted from behaviors displayed during interactions with peers as early as in toddlerhood. The predictive value of toddlerhood interaction quality is even more interesting given the low stability of behaviors during peer interaction in early childhood. The high ICCs between the two play partners' interactive behaviors showed that young children flexibly adapted their behavior to different peers. Thus, despite the variability in interaction quality across contexts, toddlers with a behavior profile of low affiliative and high antagonistic behavior frequency had a higher risk for low peer evaluation later.

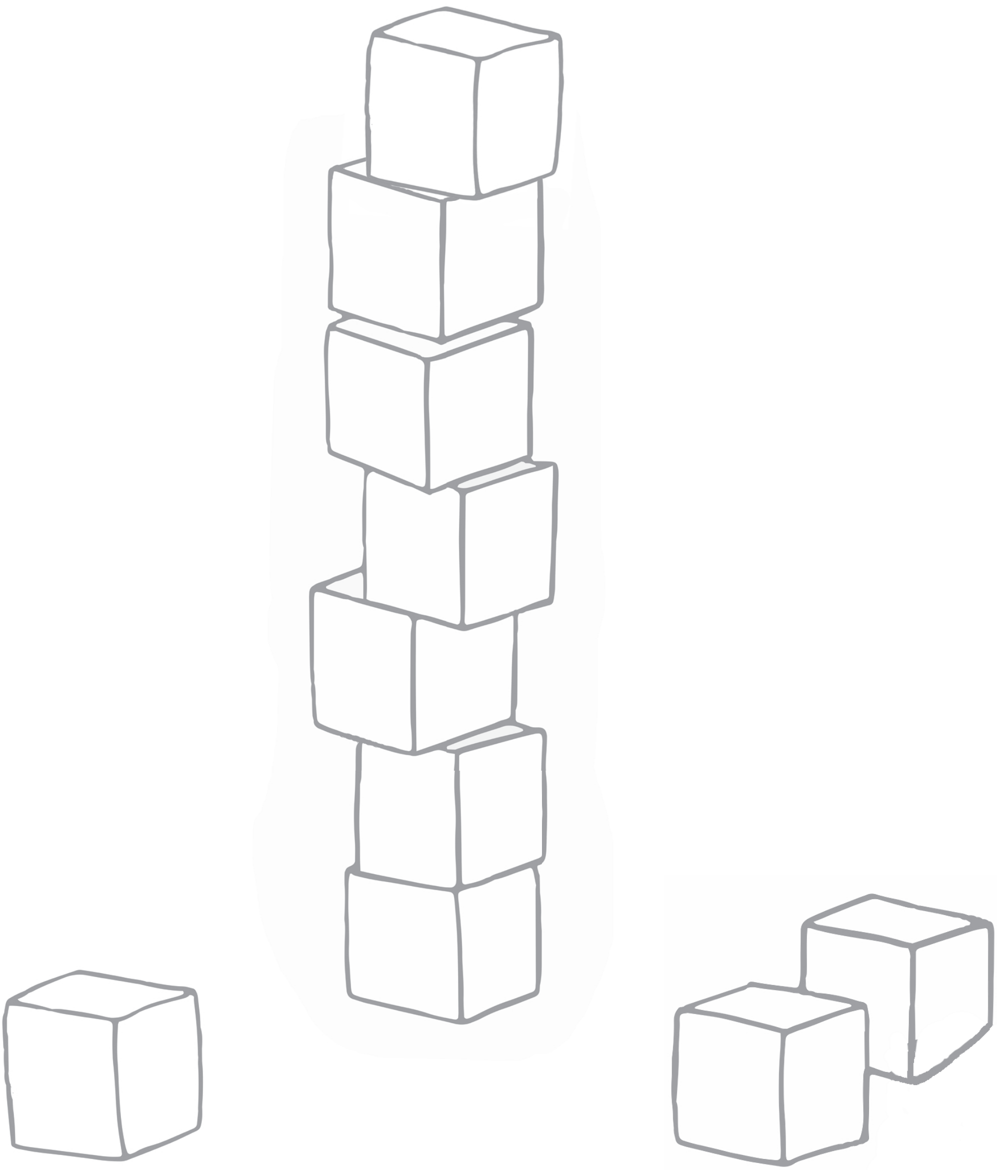
The predictive value of interaction quality for later peer preference was already evident at 2 years of age. Children who showed more frequent affiliative behaviors and less frequent antagonistic behaviors at this age were more positively evaluated by their peers at 52 months. This predictive pattern was the same for their interaction quality at 44 months, whereas no such relation was found when children were 36 months old. In the small-sample study, Friedlmeier (2009) also found an inconsistent predictive pattern of interaction quality for later peer status was found: While interaction quality in 11- to 20-month-old infants predicted their peer status in kindergarten and first grade, this was not found in 30- to 42-month-olds. These inconsistent predictive patterns for different age groups might suggest a changing role of interaction quality throughout early childhood. Indeed, it has been argued that antagonistic behavior may have a slightly different function in early childhood than in later childhood, when it is maladaptive (Dodge et al., 2006). In early childhood it may be part of normative social exploration by which young children discover how to interact with others (Vaughn et al., 2003). Yet, our results suggest that antagonistic behaviors might be maladaptive also in early childhood. The role of interaction quality across development requires investigation in order to further clarify the predictive value of affiliative and antagonistic behaviors at different ages for children's later social development.

Contrary to what we expected, we found no evidence for a predictive relation between successful action coordination and later peer preference and even a marginally significant negative prediction at 44 months suggesting higher peer preference for children who were less successful in coordinating their actions with a peer. Previous experimental studies with children suggest a positive association between proficient action coordination and social evaluation directly after the task (Kleinspehn, 2008; Plötner et al., 2015; Tunçgenç et al., 2015). Our study was novel in examining whether there is also a long-term relation between action coordination and peer preference. It is possible that successful action coordination determines immediate social evaluation when it is the only information available about the interaction partner, which was the case in previous experimental studies of the effect of action coordination on social evaluation, but becomes less influential when other social skills can be considered as well.

Alternative skills relevant during peer interaction are how children enter ongoing play of others, initiate peer interaction, or respond to an initiation (Green & Cillessen, 2007). Wilson (2006) showed that rejected children in kindergarten and first grade were more disruptive and intrusive in their entry behavior than their accepted peers. When trying to enter a play situation rejected children used high-risk strategies such as taking toys or demanding that others do something (i.e., antagonistic behaviors), while accepted children used low-risk strategies such as smiling, sharing, or imitation of others' play (i.e., affiliative behaviors). These skills could explain why we found a relation between peer interaction and later peer evaluation for children's interaction quality but not for their action coordination.

An interesting finding of our study was that both action coordination and interaction quality were highly correlated between play partners but not over time, suggesting that children flexibly adapted their behavior to each other. This adaptation when children change from one interaction context to another could be relevant in itself for children's peer preference as it might be another indicator of their social competence (Friedlmeier, 2009). Stolk et al. (2013), for example, found that 5-year-old children adapted their behavior when they believed that they were playing a game with a toddler instead of a same-aged peer, and that this adaptive competence was larger for children who spent more time in daycare. These studies suggest that flexible adaptation to different play partners is relevant for peer interaction. The consequences of flexibility in behavioral adaptation to a peer for children's later peer status are an important focus of future research.

In summary, this study adds to our knowledge of the early determinants of later peer preference. By following children longitudinally from toddlerhood to school age, we found that toddlers who showed more affiliative and fewer antagonistic behaviors during peer interaction were better liked by their peers later in school. The results also suggest that children's later peer status depended on the quality of their interaction, whereas there was no indication for a predictive relation between successful action coordination and later peer preference. Thus, interindividual differences in toddlers' interaction quality are among the earliest roots of how well liked they are by peers later in school.



General Discussion

The main aim of this thesis was to study the earliest building blocks of peer interaction by means of a cross-sectional and a longitudinal sample of 2- to 4-year-old children. How does children's interpersonal coordination develop, during cooperation as well as entrainment? What makes children perform better or worse in social interaction with peers, both in terms of interaction quality and interpersonal coordination? And does toddlers' social interaction behavior, in terms of interaction quality and interpersonal coordination, predict their later social evaluation by peers?

DEVELOPMENT OF INTERPERSONAL COORDINATION

Development of cooperation and entrainment

Studies on peer cooperation have shown that by the end of their second year of life, children only incidentally coordinate their actions during cooperation with a peer (Brownell & Carriger, 1990; Brownell et al., 2006). After their second birthday, they undergo a rapid development, making them cooperative partners at age 3 (Ashley & Tomasello, 1998; Brownell & Carriger, 1990; Brownell et al., 2006; Steinwender et al., 2010), although they continue to improve their timing after this age (e.g., Fletcher et al., 2012). Results from both the cross-sectional study (Chapter 2) as well as the longitudinal study (Chapter 5) confirm that children undergo a rapid development in cooperation between 2 and 3 years of age. While at the age of 28 months children were only incidentally successful in coordinating their behaviors during a cooperation task with a peer, 3- and (almost) 4-year-olds were successful approximately 70% of the cooperation attempts with more than 2.3 coordinated behaviors per minute.

The study of entrainment during peer drumming (Chapter 1) extended this knowledge to the development of spontaneous interpersonal coordination. Results for the cross-sectional sample showed that children also rapidly improved their spontaneous interpersonal coordination between the ages of 2 and 4. While 2- and 3-year-olds only coordinated when they did and did not drum, the 4-year-olds also rhythmically coordinated their drumming with the peer. The longitudinal findings were not presented as a separate chapter in this thesis, but confirm this developmental pattern of spontaneous interpersonal coordination: overlapping drumming with a peer rapidly improved with age, with coordination of drumming periods already present at 28 months and coordination of rhythmic behaviors emerging at age 3. Thus, in both samples children adapted their drumming to the partner by starting and stopping in a coordinated fashion from early on, but only older children tailored the rhythmic structure of drumming to each other. Together, both studies add to earlier findings that children become more successful at coordinating their behavior with external rhythms (Clizbe & Getchell, 2010; de Boer, 2012; Drake et al., 2000; Provasi & Bobin-Bègue, 2003) and adults (Kirschner & Tomasello, 2009; Kleinspehn-Ammerlahn et al., 2011) as they get older. The drumming study showed that young children also became more proficient at entraining with a peer, with a different level of coordination before and after 3 years of age.

There were similarities in the developmental pattern of interpersonal coordination during cooperation and entrainment. In addition to a rapid improvement between ages 2 and 4, the biggest changes were observed at age 3 when children became successful in cooperation and rhythmically coordinating their behaviors. Moreover, although children became more proficient in both tasks as they grew older, they were not fully proficient in interpersonal coordination by age 4, as performance was not at ceiling level (Chapters 1, 2, and 5). The findings of the studies in this thesis illustrate how young children adapt their behavior during peer interactions, both during instances of cooperation and spontaneous coordination.

Relation between cooperation and entrainment

In daily life, cooperation and entrainment are closely related and sometimes even go together in one interaction. For example, musicians intend to start a combined melody and spontaneously fall into the same tempo or accelerate together. It has been proposed that movement coordination enhances the agents' perceptual sensitivity to the motion of others and thereby fosters cooperation between the agents (Valdesolo, Ouyang, & DeSteno, 2010). Research with adults has shown that people cooperated more in a game after having experienced coordination during walking or singing a song (Wiltermuth & Heath, 2009). Moreover, when participants cooperated by communicating with each other to solve a puzzle task, their body movements were better coordinated than when they just conversed without such a common goal (Shockley et al., 2003).

The relation between cooperation success and children's performance on the entrainment task was not explicitly addressed in any of the chapters in this thesis, but explored in the longitudinal sample. The correlation between cooperation success and children's amount of overlapping drumming was positive but not significant: 28 months (n = 82): $r = .21$, $p = .05$; 36 months (n = 112): $r = .01$, $p = .89$; 44 months (n = 120): $r = .02$, $p = .81$. The relation between cooperation success and children's rhythmic coordination during drumming was negative and only significant at 28 months: 28

months (n = 88): $r = -.22$, $p = .04$; 36 months (n = 118): $r = -.13$, $p = .17$; 44 months (n = 120): $r = -.15$, $p = .10$. These weak and inconsistent results complement earlier findings by Shockley et al. (2003), Valdesolo et al. (2010), and Wiltermuth and Heath (2009), although there is one essential difference. In this thesis interindividual differences between children were studied. The earlier studies compared performance between conditions: Participants in a coordination condition showed better cooperation than participants without interpersonal coordination experience (Valdesolo et al., 2010; Wiltermuth & Heath, 2009), or coordinated better in a cooperative condition than in a non-cooperative condition (Shockley et al., 2003). The experience of cooperation might make people more likely to coordinate spontaneously with a partner and vice versa, but that they coordinate well spontaneously with others might not imply that they will also be good at interpersonal coordination when a joint goal is involved. A controlled experimental setup in which participants face multiple coordination tasks would inform us to what extent interindividual differences in interpersonal coordination are the basis for differences in cooperation and entrainment. Examining the reasons for interindividual differences in cooperation and entrainment, as discussed in the next section, has the potential to clarify the underlying mechanisms of cooperation and entrainment that may explain why performance in the cooperation and entrainment tasks was not related.

INTERINDIVIDUAL DIFFERENCES IN PEER INTERACTION

Mirroring as underlying mechanism for interpersonal coordination

In Chapters 2 and 3, we studied interindividual differences in interpersonal coordination from two different perspectives. Whereas in Chapter 2 characteristics of the child and their experience with peers were studied, in Chapter 3 the focus was on interindividual differences in neural mirroring. It has been suggested that the mirror system plays an important role in facilitating interpersonal coordination (e.g., Bekkering et al., 2009; Hari & Kujala, 2009; Phillips-Silver & Keller, 2012). Both when we execute and when we observe an action, our motor system becomes activated (Marshall & Meltzoff, 2011; Rizzolatti & Craighero, 2004). By means of EEG, this sensorimotor coupling is observed by a reduction of mu- and beta-power over motor areas (cf. Pavlidou, Schnitzler, & Lange, 2014; Pineda, 2008; Vanderwert et al., 2013). It is assumed that when our motor system becomes activated during the observation of others' actions, we can predict others' actions more accurately and adapt our own actions accordingly (Kourtis et al., 2013; Sebanz et al., 2006). Consistent with this account we found that children who showed higher levels of motor involvement during the observation of actions were also better at coordinating their actions with peers during cooperation (see Chapter 3). However, we did not find evidence for a relation between children's mirroring of actions and their level of spontaneous interpersonal coordination. Thus, the mirror system might underlie planned and spontaneous interpersonal coordination skills differentially.

One possible explanation for the difference in results between cooperation and entrainment is that an action goal is important for the response of the mirror system (Koski et al., 2002). It has been argued that especially in cooperation, it is more important to monitor and predict another person's goals than it is to predict their movements (Bekkering et al., 2009). Similarly, in the current cooperation task, children had to assume complementary roles that required monitoring of each other's actions. In the entrainment task, there was no common goal, as children were not instructed to coordinate their drumming. In contrast with our findings, Naeem et al. (2012) found a relation between entrainment and mu-band activity. In this study participants were instructed to coordinate their finger-tapping in-phase or anti-phase. The fact that participants intended to coordinate in the study of Naeem et al. – in contrast to the drumming task in the current study – might explain why they found a significant relation.

There is also evidence for the relevance of neural mirroring during spontaneous coordination when there is no common goal. Motor interference studies provided indirect evidence as participants showed interference in their rhythmic behavior (i.e. moving the arm horizontally) when they observed another rhythmic behavior at the same time (i.e. moving the arm vertically: Blakemore & Frith, 2005; Kilner, Paulignan, & Blakemore, 2003; Marshall, Bouquet, Thomas, & Shipley, 2010; Saby, Marshall, Smythe, Bouquet, & Comalli, 2011; van Schaik, Endedijk, Stapel, & Hunnius, 2016). This interference is likely caused by the overlapping representations of the observed and executed behavior due to mirroring (Blakemore & Frith, 2005; Kilner et al., 2003). There are also some studies that directly measured neural mirroring in spontaneous coordination tasks. For example, Tognoli, Lagarde, de Guzman, and Kelso (2007) found that not the mu rhythms but phi rhythms were sensitive to the level of spontaneous interpersonal coordination in a finger-tapping task, as phi could distinguish between successful and unsuccessful coordination. Hogeveen and Obhi (2012) found that participants who spontaneously copied the behaviors of others during a social interaction afterwards showed more activation of the motor system during the observation of hand movements. These studies suggest that the mirror system also plays a role in spontaneous interpersonal coordination when there is no goal involved, although the activation of the motor system might be slightly different.

Another possible explanation for the different results between the cooperation and entrainment task is that the mirror system might be involved in both tasks, but that no relation with entrainment was found due to the measures of entrainment we used. As children were not instructed to coordinate their behavior with each other, we chose a measure that would capture a relatively broad range in behavioral coordination patterns: in principle coordination could occur in-phase, anti-phase, or with a longer lagged relation between their drumming in which one child performed a rhythm and the other child replicated that rhythm afterwards. Therefore, we used maximum cross-correlations to measure the coordination of children's drumming rhythms with each other independently of whether they produced the same rhythm at the same time or with a time delay. If the mirror system underlies entrainment, it is expected that simulating the actions of a partner would be most helpful for coordination of rhythmic behaviors at that exact point in time, as action simulation of the partner's action takes places at the same time as participant's own action planning (Vesper, van der Wel, Knoblich, & Sebanz, 2013). By using maximum cross-correlations, the time of coordination was removed from the level of rhythmic coordination. As a result, we may not have measured coordination at a level at which the mirror system underlies interpersonal coordination.

Other mechanisms underlying interpersonal coordination

Beyond mirroring, other mechanisms may underlie spontaneous interpersonal coordination. Why do we coordinate spontaneously with the rhythmic actions of others or even a metronome? Besides sensorimotor coupling, Repp and Su (2013) propose that the internal representation of a given tempo also plays a major role in rhythmic behaviors. This suggests that an internal timekeeping mechanism or oscillator drives the taps by controlling the tapping tempo (Repp, 2005). Entrainment would then occur when the oscillators of both partners become entrained (Richardson et al., 2007; Schmidt & Richardson, 2008). This coupling is enhanced by visual contact (Schmidt & Richardson, 2008). Varlet, Bucci, Richardson, and Schmidt (2015) tested possible explanations for enhanced entrainment by visual tracking and found that it was not due to rhythmic movements of the eyes, but due to an increased amount of visual information available. Keller (2008) proposed that this visual observation recruits the mirror system to interact with the timekeeper mechanisms in order to coordinate with others. This explains how we spontaneously adapt our timing in order to entrain with someone else's timekeeper. Thus, the timekeeping mechanisms is involved in rhythmic behavior, but in order to reach coordination the mirror system still has an important role.

Chapter 2 suggests that besides mirroring, also in cooperation additional mechanisms are involved. In this chapter effortful control appeared to be relevant for children's interpersonal coordination. This finding implies that cognitive processes are relevant for cooperation, as effortful control captures children's tendency to inhibit behaviors in interactions (Rothbart, Ahadi, Hershey, & Fisher, 2001). Indeed, inhibitory control has been shown to play an important role for children's cooperation skills (Meyer, Bekkering, Haartsen, Stapel, & Hunnius, 2015). In addition, other studies have demonstrated the importance of other cognitive skills as planning (Gerson et al., 2013; Meyer, van der Wel, & Hunnius, 2016; Warneken, Steinwender, Hamann, & Tomasello, 2014) and monitoring (Vesper et al., 2010). Thus, cooperation requires additional cognitive processes.

Taken together, mirroring is assumed to be a relevant mechanisms for both entrainment (Phillips-Silver & Keller, 2012; Smith, 2008) and cooperation (Kourtis et al., 2013; Oberman et al., 2007; Vesper et al., 2013). The above reasoning suggests that cognitive skills are relevant for interpersonal coordination during cooperation, and timekeeping mechanisms are relevant for interpersonal coordination during entrainment. More research is needed to further clarify the role of these and possibly other mechanisms in interpersonal coordination.

SOCIAL EFFECTS OF PEER INTERACTION

Social effects of interaction quality and interpersonal coordination

Previous studies have found an association between interaction quality and children's preference by peers (e.g., Johnson et al., 2000; Keane & Calkins, 2004; Nelson et al., 2010; Rubin et al., 1982; Sette et al., 2013; Vaughn et al., 2003; Wilson, 2006). We extended these findings by demonstrating that children who showed more affiliative behaviors and fewer antagonistic behaviors already at the age of 28 months were more preferred by their peers later in school (Chapter 5). Therefore, interindividual differences in toddlers' interaction quality are amongst the earliest roots of how well liked they are by their peers later in life.

Earlier studies have found an increase in children's helping behavior after experiencing coordination (Cirelli et al., 2014; Hamann et al., 2012; Kirschner & Tomasello, 2010). There were also some first indications of an effect of interpersonal coordination on social evaluation by children (Tunçgenç et al., 2015). In contrast, we did not find a relation between children's interpersonal coordination and their social evaluation by peers, neither for the cooperation task (Chapter 5) nor the entrainment task. While previous experimental studies have shown a relation between interpersonal coordination and rapport or liking (e.g., Hove & Risen, 2009; Lakens & Stel, 2011; Miles et al., 2009; Plötner et al., 2015), we could not extend these findings to peer interactions and a later social evaluation. Apparently, interpersonal coordination is important for immediate social evaluation when there is no other information about the interaction partner available to base preference on, but becomes less relevant on the long run when other social skills also come into play. This is supported by Kirschner and Irali (2014) who failed to find social effects of joint drumming in a experimental setup where also other social skills might have played a role as the prosocial tests and joint drumming were embedded in a play situation.

Mechanism underlying the social effects of interpersonal coordination

What is it exactly in interpersonal coordination that creates these social effects? Lakens and Stel (2011) found that the relation between interpersonal coordination and ratings of rapport was mediated by the degree to which individuals feel that they form a social unit. Kirschner and Tomasello (2010) also suggested that interpersonal coordination highlights a 'we-unit' in children and therefore increases prosocial behavior. Whether this 'social unit' is purely perceptual in nature, as Marsh, Richardson and Schmidt (2009) propose, or also extends to psychological similarity is currently unclear. During interpersonal coordination, high levels of coordination result in increased perceptual sensitivity (Valdesolo et al., 2010) and perceptual similarity (Lakens & Stel, 2011). There are indications that psychological similarity is established, as interaction partners often respond empathically and thus coordinate their affective behavior (Keller, 2008; Phillips-Silver & Keller, 2012; Rochat, 2007). Hereby, the emotions of the other are in accord with our own emotions, which results in experiencing the other as part of our psychological self. This psychological similarity could result in enhanced liking of the interaction partner, as we project our positive feelings of the self onto the other, resulting in increased affiliation for partners who coordinate well.

The mirror system may possibly explain this effect of interpersonal coordination via psychological similarity to liking. Cacioppo et al. (2014) found evidence for a role of the mirror system in psychological similarity. They showed involvement of brain areas in interpersonal coordination that are relevant for social cognition, embodied cognition, self-other expansion, and action observation, such as the inferior parietal lobule and the ventro-medial prefrontal cortex. Gallese (2006) assumes that the mirror system is also the neural underpinning responsible for the experience of the same emotion or sensation as an interaction partner. Thus, interpersonal coordination makes us feel more like a social unit as the perceptual and affective similarity caused by the mirror system resulting in increased positive feelings to each other.

Many studies demonstrated enhanced interpersonal coordination between participants who felt more socially connected (see Lakin, 2012 for a review). For example, increased interpersonal coordination has been found between people who like each other (McIntosh, 2006) or for people who have a more prosocial orientation (Lumdsen et al., 2012; Marsh et al., 2013; Stel, Rispens, Leliveld, & Lokhorst, 2011), and interpersonal coordination is disrupted during an argument (Paxton & Dale, 2013a) or when a partner was late (Miles, Griffiths, Richardson, & Macrae, 2010). How does liking result in increased interpersonal coordination? When we like each other, we tend to attribute the same characteristics to the other as to ourselves and take the perspective of the other as actor (Aron, Aron, Tudor, & Nelson, 1991). This increased attention to the other probably boosts our mirroring (Keller, 2008; Kinsbourne & Helt, 2011; Macrae, Duffy, Miles, & Lawrence, 2008; Miles, Lumdsen, Richardson, & Macrae, 2011; Richardson et al., 2007). Indeed, neuroimaging studies have found enhanced mirroring when participants felt more connected to a partner (Aragón, Sharer, Bargh, & Pineda, 2014), when participants were socially primed (Hogeveen & Obhi, 2012; Oberman et al., 2007) and for in-group members compared with out-group members (Gutsell & Inzlicht, 2010; Molenberghs, 2013; Molenberghs et al., 2013; Rauchbauer et al., 2015). Moreover, increased mirroring was found for a higher degree of involvement in social interaction (Kilner, Marchant, & Frith, 2006; Meyer et al., 2011). As enhanced mirroring is suggested to result in better interpersonal coordination (e.g., Chapter 3, Bekkering et al., 2009; Hari & Kujala, 2009; Phillips-Silver & Keller, 2012), this suggests that liking, via feeling as a social unit and the mirror system, results in increased interpersonal coordination. Thus, mirroring results in increased feelings of being a social unit with a partner and can be socially facilitated due to increased attention resulting in increased interpersonal coordination.

Measuring social effects of peer interaction

If the mirror system is relevant for the social effects of interpersonal coordination and leads to increased interpersonal coordination, what does that imply for the measurement of the social effects of interpersonal coordination in peer interaction? In previous studies various measures have been used ranging from helping and trust to rapport and affiliation (Aron et al., 1991). The path from interpersonal coordination to liking and vice versa as described above seems to be an unconscious process. This could imply that the social effects are not explicit, but only implicit. Plötner et al. (2015) indeed showed a difference in implicit and explicit liking: they found an effect of interpersonal coordination on implicit liking as measured via helping behavior and affiliation, but not for explicit liking as measured via direct questions about trust and liking. Using implicit ratings to measure peer evaluation may provide more insight in social effects of interpersonal coordination as they occur in children's daily interactions.

Whereas a helping task is suitable to measure implicit liking of one peer for the child, it is not feasible to measure the preference of multiple peers for this child. The sociometric procedure, of which we developed a reliable and valid computerized version for young children (see Chapter 4), could provide new opportunities for the development of an implicit rating method for multiple peers. The procedure of paired comparisons might be mainly interesting. In this method, children are presented with pictures of all possible pairs of classmates. This procedure could be combined with eye-tracking, which is often used in research with infants to measure their attention to stimuli or their prediction or anticipation (Gredebäck, Johnson, & von Hofsten, 2010). Earlier eye-tracking research has shown a bias in the first gaze towards the item that is liked more (Schotter, Berry, McKenzie, & Rayner, 2010). In line with this finding, eye-tracking during computerized paired comparisons could possibly be used to see how much classmates are liked implicitly by their peers. This implicit measure would be very suitable for young children as no instruction has to be given and the only response is looking behavior. This would make it possible to measure the social effects of interpersonal coordination already before the age of 4 for example in day care settings.

CHALLENGES AND BENEFITS

Interpersonal coordination is reached when at least one of the two interaction partners accommodates his or her actions to the other (Cacioppo et al., 2014). Therefore, whether a well-coordinated interaction emerges between two people does not only depend on one's own interpersonal coordination skills but also on those of the other. One might even reach perfect coordination by not paying attention at all to one's partner if it is the partner who is adjusting his or her actions. When studying interaction, neither the dynamics of the process nor co-regulation between partners can be observed when participants are studied independently from one another (Dumas, Laroche, & Lehmann, 2014). A child's behavioral score can be an over- or underestimation of children's competence, if the dependency of the interaction partners is not taken into account (Friedlmeier, 2009). Surprisingly, there are only a few interaction studies with children that took the dyadic process into account (but see Friedlmeier, 2009; Fukuyama et al., 2014; Hunnius et al., 2009; Williams et al., 2010).

As expected, we found high intraclass correlations (ICCs) between the interactive behaviors and interpersonal coordination of two children (Chapters 1, 2, 5). We also found that children showed so much flexibility to different interaction partners that there was only a very low degree of behavioral stability for the individual children over consecutive time points (Chapter 5). This is the logical result of studying children in interaction, as children's behavior varies in response to fluctuations in the social situation such as the partner's characteristics, overtures, and responses (Rubin et al., 2006). This strong dependency on the partner's behavior and high variability between time points made the study of relations between different variables challenging, as this dyadic dependency resulted in additional noise in the data. Moreover, for different research questions, different analytic approaches of individual and dyadic data, and sometimes even a combination of dyadic and individual analyses (see Chapter 2) had to be used.

Seeing children as dyadic partners that highly influence one another also resulted in new insights in the development of peer interaction. The flexibility of children's behavior is interesting in itself, as children face different peers in their daily interactions. In order to successfully cooperate they have to be flexible in accommodating to their peers. Indeed, earlier research on interpersonal coordination during a joint finger tapping task revealed that responsiveness to the partner is very important, which implies both accommodating to the partner's actions as well as waiting for the partner 's actions (Konvalinka et al., 2010). There are even indications that mutuality in interaction is an indication of social competence (Friedlmeier, 2009). The level to which flexibility in peer interaction is relevant for children's social evaluation and their social development is an important focus for future research.

The dyadic process in itself is also an interesting focus for future research. For example, in a coordination study with adults Melendez-Calderon, Komisar and Burdet (2015) found that each dyad had a specific cooperation strategy that did not seem to be inherent to individual capabilities but emerged in each dyad. Schmidt and Richardson (2008) showed that dyads that were heterogeneous in social competence were better at interpersonal coordination than pairs with comparable levels of social competence. This raises questions about how dyadic coordination develops over the course of an interaction and whether predictions can be made about children's interaction success given the combination of their own and a partner's characteristics. As researchers are overcoming the challenge of analyzing datasets with dyadic dependency, a whole field of research on interaction processes lies ahead of us.

IMPLICATIONS

This thesis bridges cognitive and developmental psychology by studying personal and neural differences underlying the development of interpersonal coordination during cooperation and entrainment tasks, its interplay with interaction quality, and its relation with later peer preference. The findings of this thesis inform both research fields as well as professionals working with children in early childhood.

Development of interpersonal coordination

First, we found that interpersonal coordination with a peer undergoes significant changes during the third year of life, both during cooperation and entrainment situations. This extends findings of earlier cooperation studies to interpersonal coordination in which there is no common goal. As entrainment is part of children's daily interactions (Marsh et al., 2009) occuring for example during joint music making or playing team sport, this thesis provides more insight in children's interpersonal behavior at different moments during their development. Our results reveal the developmental pattern of interpersonal timing. Children first act at the same time by drumming jointly, before they start coordinating their timing at a more advanced level by coordinating their drumming rhythms (Chapter 1). Our results suggest that the temporal aspect of interpersonal coordination is not one dimension on which children improve as they get older. Instead, interpersonal coordination develops in several temporal domains, with children first coordinating broadly in time by coordination their periods of drumming. As soon as they reach a certain level of overlap in their drumming, they develop coordination at a more detailed time level, by coordinating their rhythmic behaviors.

Studies with adults have revealed that dyadic behavior is coordinated at multiple time scales (Toiviainen, Luck, & Thompson, 2010) varying from milliseconds to hours (Semin & Cacioppo, 2008). Our results provide a developmental view on this multiple time scale perspective. Children first develop a window of opportunity for interpersonal coordination by acting more and more at the same time. When this window of opportunity grows, children begin to coordinate the timing of their behaviors by coordinating their rhythmic behaviors. Once they establish rhythmic coordination, they develop coordination of their rhythmic behaviors on a hit-to-hit basis as is found in adults (Konvalinka et al., 2010), although this was not directly reflected in our data.

This development at multiple time scales is probably not restricted to actions alone, but can also be found in other behavioral modalities in which dyads show coordination, such as language, facial expressions, and posture (Louwerse et al., 2012). The pattern for action coordination looks similar to the developmental pattern that has been found in studies on turn-taking in communication. In the first few weeks of life children create possibilities for communication by orienting to people's faces and especially their eyes and mouths (Reddy et al., 1997), similar to the window of opportunity children create by acting at the same time. This social orientation increases with age, and from 3 to 4 months children are regularly involved in proto-conversations in which they take turns (Gratier et al., 2015; Reddy et al., 1997; Tomasello, Carpenter, & Liszkowsi, 2007). During these proto-conversations infants improve the timing of their turn-taking, for example by decreasing vocalization overlap (Hilbrink, Gattis, & Levinson, 2015). Thus, turn-taking in communication also seems to develop from a broad level of temporal coordination to timing at a more detailed level. This suggests that development of behavioral coordination at multiple timescales is not only restricted to action coordination but probably also present in the coordination of other behaviors.

Mirror system in relation to interindividual differences in interaction

The current results are informative for both cognitive and developmental psychology, as they shed light on the role the mirror system might play in interpersonal coordination. Our results indicate a relation between neural mirroring and successful interpersonal coordination in social interactions (Chapter 3). We extend earlier findings of a task-specific relation between the mirror system and behavioral performance during the same laboratory task and show that interindividual differences in motor activation during action observation are closely related to various instances of social interactions with peers. Our results suggest that how much the mirror system becomes engaged by observing the actions of others underlies the degree of interpersonal coordination and thus successful social interaction.

In line with the idea of stable interindividual differences in mirroring as basis for social interaction are previous findings of a relation between mirroring and social-cognitive abilities such as perspective taking (Woodruff et al., 2011) and empathy (Gazzola et al., 2006; Hooker et al., 2010; Kaplan & Iacoboni, 2006). This does not rule out that the mirror system can be flexible due to situational effects (e.g., Aragón et al., 2014; Meyer et al., 2011; Rauchbauer et al., 2015) or that mirroring can be enhanced by sensorimotor training (Cook, Bird, Catmur, Press, & Heyes, 2014). For example, enhanced perceptual sensitivity gained during coordination might generalize to other interpersonal coordination situations with new interaction partners (Valdesolo et al., 2010). Whether mirroring abilities are indeed a stable interindividual characteristic should be addressed in further research.

Interactive behavior and peer evaluation

Despite a large variability in children's interaction quality across different situations, toddlers who display a low frequency of affiliative behaviors and a high frequency of antagonistic behaviors at 28 months seem to be at risk for low peer evaluation at preschool. At the same time, the frequency of these interactive behaviors highly depended on the peer's behaviors. This may have two implications for professionals who work with young children. On the one hand, it suggests that a child who shows frequent antagonistic behaviors and infrequent affiliative behaviors might be able to interact in other, more positive ways, if paired with the right peers. In this respect, it may be helpful to let the child play with other children who are skilled in interactions and display frequent affiliative behaviors. Important in this respect is that once the child acquires a broader range of behaviors the child can be more competent in social interactions (Vaughn et al., 2003; Williams et al., 2007, 2010). On the other hand, the picture of a highly antagonistic child should be placed in perspective: The child behaves antagonistically given the situation and the interaction partner, but can probably behave more affiliatively in other contexts. Conversely, a socially competent child does not always interact affiliatively (see also Friedlmeier, 2009). Thus, children's behavioral profiles are always dynamic, but socially competent children are able to achieve a balance between meeting their own needs and maintaining positive relations with peers (Green & Rechis, 2006).

These implications indicate that once children acquire a low status due to the regular antagonistic behaviors and infrequent affiliative behaviors, they may enter a vicious circle. Once low sociometric status is acquired, children's interaction experiences with peers change (Ladd, 2006). In this case, children are restricted in their interactions to other children with the same excluded status and the same behavior profile (Ladd, 2006), further increasing each other's antagonistic behaviors. To learn other problem-solving strategies it is important to regularly switch interaction partners (NICHD Early Child Care Research Network, 2008), but a low status child has fewer opportunities for this than others.

Conversely, both implications reveal that if a child shows problem behaviors in peer interactions, it is important to examine the interactions in detail. Informative in this respect is the study of Delaherche et al. (2013) who studied the interaction between children with Autism Spectrum Disorder (ASD) and their therapists: the therapists adapted their communicative behavior to the child with ASD, whereby the behavior of the therapists informed us of the child's characteristics. Just as in these interactions between therapist and child with ASD, in peer interaction information of the child's behavior can be extracted from the behavior of the interaction partner. In this way, the behavior of the peer or the context in which the problem behaviors occur might already provide indications for adjustments aimed at changing the child's interactive behavior and subsequent social status.

CONCLUSIONS

This series of studies reveals that an important part of the development of peer interaction takes place in the third year of life. Studying the earliest building blocks of peer interaction in early childhood provided new insights in the early development of interpersonal coordination, its interplay with interaction quality, factors that contribute to interindividual differences in peer interaction, and consequences for later evaluation by peers. The mirror system likely plays an important role in this developmental process and future research should further examine its stability and the level to which it underlies different forms of interpersonal coordination and its social effects. Although challenging, to obtain a more in-depth understanding of peer interaction processes that are probably related to children's social status in school and their further social development, a dyadic perspective in interaction studies is needed.

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English Summary

The aim of this thesis was to study the earliest building blocks of peer interaction. A cross-sectional sample of 2-, 3- and 4-year-old children was studied to investigate the development of interpersonal coordination during peer interaction. In addition, the 180 2-year-olds were followed longitudinally until the age of 4 to study the relation between their early peer interaction and later peer relations. Mapping the time course of interpersonal coordination abilities in young children, both during entrainment and cooperation, and the interplay of interpersonal coordination with interaction quality enriched our understanding of children's social development.

Chapter 1 describes a cross-sectional study on the development of entrainment during spontaneous drumming. We assessed children's coordination both by the relative amount of overlapping drumming and the correspondence of their rhythmic behaviors. Both measures indicated that older children coordinated more than younger children. All children spontaneously adapted their drumming behavior to their partner by pausing and drumming in a coordinated fashion, but only 4-year-olds adapted the rhythmic structure of their drumming to their partner's drumming. All age groups showed similarly stable drumming, but younger children could maintain it for only a short time, which may have limited the possibilities to coordinate their hits. Like adults, children may require some time to coordinate interpersonally, in which case a longer sustained rhythm might help them to adapt their behavior to a partner. Children were not equal in their coordination attempts. Periods of overlapping drumming tended to be initiated by one of the dyad members, while the other child followed. Our results suggest that when children's drumming is not continuous but characterized by periods of closely related hits and pauses, it is informative to study the coordination of these drumming periods.

In Chapter 2, age-related changes in cooperation were examined in a cross-sectional study using a peer cooperation task. Moreover, individual characteristics and experiences with peers were explored to explain individual differences in cooperation. The findings highlighted how quickly peer cooperation develops in young children. Whereas 2-year-olds coordinated their actions only infrequently, 3- and 4-year-olds were very proficient at cooperation. Children who showed more affiliative behaviors also were more successful in the cooperation task, whereas no association with antagonistic behaviors was found. The association of child characteristics with interaction behavior was stable across age: The same child characteristics predicted affiliative behaviors during peer cooperation among 2-, 3-, and 4-year-olds. Temperamental surgency was positively associated with affiliative behavior, whereas negative affectivity was associated negatively with affiliative behavior. Children who were more active and extroverted and less shy (according to their parents) thus displayed more affiliative behavior. At all ages girls showed more affiliative behavior than boys. Furthermore, there was a direct effect of temperament on cooperation success. Children with better effortful control or behavioral inhibition (according to their parents) showed more cooperation success. For 4-year-olds, there was also a positive association of their early experiences with peers in child care and their cooperation success. In summary, among young children temperament primarily influences cooperation, but as they grow older their previous experiences with peers in child care also come into play.

In Chapter 3, the results were reported of an EEG-study on the neurocognitive processes that might underlie interindividual differences in interpersonal coordination. A subsample of 4-year-old children from our longitudinal sample observed an adult model engaging in various actions (e.g., stacking cups) and we subsequently measured their neural level of mirroring. Children who showed more motor system involvement when observing actions (as indicated by a relative reduction in beta power), showed better cooperation with peers during their earlier assessments at 2 to 4 years of age. The explained variance was high, suggesting that interindividual differences in mirroring are very relevant for interpersonal coordination with peers in early childhood. Thus, beyond the known relation between mirroring and coordination performance in the same laboratory task, interindividual differences in mirroring may generalize to social interactions outside the specific task. The findings suggest that interindividual differences in neural mirroring in early childhood may underlie interpersonal coordination and thus successful social interaction.

In Chapters 4 and 5, children's peer evaluations were examined. Chapter 4 described a methodological sociometric study in a preschool sample for which a computerized method was developed and compared to offline sociometric assessments. Children were asked to rate how much they liked to play with each of their classmates (yes; sometimes yes and sometimes no; no). Based on the ratings of all classmates, children's preference among peers was calculated as well as their sociometric status (accepted, rejected, controversial, neglected, average). In the offline method, children were asked to assign pictures of classmates to three boxes representing the three answer categories. In the computerized method, pictures were presented on the screen and children clicked on one of three smileys corresponding to the categories. Both methods yielded comparable distributions of ratings and status groups and only small differences in correlations among the three answer categories. There were no differences in the internal consistency of the ratings that was generally high, indicating the measurement of homogeneous constructs. There were small differences in interrater reliability that was generally low, indicating the typical fact that children differ in their peer preferences. The computerized assessment provided additional data for further analysis of the peer evaluation process, such as response tendencies over the course of the experiment. We concluded that computerized peer ratings are a promising tool for sociometric measurement with preschool children that provide comparable results as offline assessments. The computerized version has the additional advantage of providing more information about children's answer tendencies. It also offers opportunities for the further improvement of sociometric research, for example by providing visual or auditory support. Such improvements may make sociometric methods even more suitable for younger children or suitable for children with special needs.

Chapter 5 described a longitudinal study in which we examined whether interpersonal coordination and interaction quality in toddlerhood predicted peer preference at school, measured via the computerized peer ratings method. By following children longitudinally from toddlerhood to school age, we found that toddlers who showed more affiliative and fewer antagonistic behaviors during peer interaction in the cooperation task were better liked by their peers later in school. There was no predictive relation between successful action coordination and later peer preference. The predictive value of toddlerhood interaction quality is particularly interesting given the low stability of dyadic behaviors. Children who showed frequent affiliative behaviors at 2 years of age were not among those high in affiliative behaviors at 3 or 4 years of age. High positive intraclass correlations between the two play partners' affiliative and antagonistic behaviors showed that young children flexibly adapted their behavior to different peers. Hence, despite large variability in interaction quality across different situations, toddlers with a behavior profile of low affiliative and high antagonistic behavior seemed at risk for low peer evaluation later. The predictive value of interaction quality for later peer preference was already evident at 28 months. Thus, interindividual differences in toddlers' interaction quality are among the earliest roots of their social preference by peers later in school.

Nederlandse Samenvatting

Het doel van dit proefschrift was om de eerste bouwstenen van sociale interacties tussen jonge kinderen te bestuderen. We observeerden kinderen van twee, drie en vier jaar tijdens het samen spelen met een leeftijdsgenoot om de ontwikkeling van gedragsafstemming te bestuderen. De 180 tweejarigen werden tevens longitudinaal gevolgd tot de leeftijd van vier om de relatie tussen hun vroege interacties en latere relaties met leeftijdgenoten te onderzoeken. Dit onderzoek heeft ons begrip van de sociale ontwikkeling van kinderen verrijkt, door de ontwikkeling van gedragsafstemming bij jonge kinderen in kaart te brengen, zowel tijdens een coöperatietaak als een entrainment taak, en door de samenhang tussen gedragsafstemming en de kwaliteit van de sociale interacties te bestuderen.

In hoofdstuk 1 bestudeerden we de ontwikkeling van entrainment tijdens spontaan trommelen van twee-, drie- en vierjarigen. Om te meten hoe goed ze hun gedrag op elkaar afstemden, bekeken we zowel de relatieve tijd dat ze gezamenlijk trommelden, als ook de overeenkomst tussen hun trommelritmes. Uit beide metingen bleek dat oudere kinderen hun gedrag beter op elkaar afstemden dan jongere kinderen. Alhoewel alle kinderen spontaan hun trommelen aanpasten aan dat van hun partner door hun pauzes en periodes van trommelen op elkaar af te stemmen, pasten alleen vierjarigen ook de ritmische structuur van hun trommelen aan. De stabiliteit van de trommeltempo's van de kinderen verschilden niet tussen de leeftijdsgroepen, maar jongere kinderen konden een stabiele trommeltempo maar korte tijd volhouden. Dit beperkte de mogelijkheid om hun trommelritme af te stemmen op het trommelritme van hun partner. Waarschijnlijk hebben kinderen, net zoals volwassenen, enige tijd nodig om gedrag af te kunnen gaan stemmen, waarbij een langer aanhoudend ritme hen zou kunnen helpen om hun gedrag aan te passen aan hun partner. Kinderen pasten hun trommelen niet gelijkwaardig aan elkaar aan, aangezien periodes van samen trommelen herhaaldelijk werden begonnen door hetzelfde kind, waarbij het andere kind volgde. Deze resultaten laten zien dat voor het bestuderen van gedragsafstemming in kinderen ook de afstemming tussen periodes van trommelen informatief is.

In hoofdstuk 2 werd in dezelfde groep kinderen de ontwikkeling van gedragsafstemming tijdens een coöperatietaak onderzocht. Bovendien werden kindkenmerken (zoals temperament) en eerdere ervaring met leeftijdsgenoten meegenomen bij de voorspelling van individuele verschillen in coöperatie. Tijdens de coöperatietaak moesten kinderen een poppetje van boven door een van twee glijbanen laten glijden en aan de onderkant opvangen in een zwembadje. De glijbanen waren te lang voor één kind om zowel het poppetje te laten glijden als op te vangen. Daarom moesten de kinderen goed op elkaar letten en hun gedrag op elkaar afstemmen. De resultaten bevestigden hoe snel gedragsafstemming zich ontwikkelt bij jonge kinderen. Terwijl tweejarigen hun handelingen zelden afstemden waardoor het poppetje meestal op de grond viel, konden drie- en vierjarigen zeer goed samenwerken. Kinderen die tijdens de coöperatietaak meer affiliatief gedrag vertoonden, zoals speelgoed delen en het andere kind helpen, waren ook meer succesvol in het afstemmen van hun gedrag tijdens de taak. Er was echter geen verband tussen gedragsafstemming en antagonistisch gedrag, zoals speelgoed afpakken of claimen. Voor twee-, drie- en vierjarigen voorspelde dezelfde kindkenmerken affiliatief gedrag tijdens coöperatietaak. Kinderen met een meer actief en extravert temperament (volgens hun ouders) en minder angst waren meer affiliatief. Op alle leeftijden waren meisjes meer affiliatief dan jongens. Temperament hing samen met gedragsafstemming op de coöperatietaak: Kinderen met meer gedragscontrole (volgens hun ouders) waren meer succesvol. Bij vierjarigen hing succesvolle afstemming van gedrag ook samen met eerdere ervaringen met leeftijdsgenoten in de kinderopvang. Kortom, op jonge leeftijd was voornamelijk temperament van belang voor samenwerken, maar naarmate de kinderen ouder waren, werden ook eerdere ervaringen met leeftijdsgenoten in de kinderopvang van belang.

Hoofdstuk 3 rapporteert een EEG-onderzoek over de neurocognitieve processen die mogelijk ten grondslag liggen aan individuele verschillen in gedragsafstemming. Vierjarige kinderen uit de longitudinale groep observeerden een volwassen model dat verschillende handelingen uitvoerde (zoals het stapelen van kopjes) en we registreerden de mate waarin de hersenen van de kinderen deze handelingen meededen of spiegelden. Kinderen die hun motorische systeem meer betrokken bij het observeren van acties (zoals gemeten door een relatieve vermindering van beta-golven), stemden hun gedrag meer af op hun leeftijdsgenoot tijdens de coöperatietaak op twee- tot vierjarige leeftijd. De verklaarde variantie was hoog wat suggereert dat individuele verschillen in neuraal spiegelen erg belangrijk zijn voor gedragsafstemming van kinderen. Het is mogelijk dat de samenhang tussen neuraal spiegelen en gedragsafstemming tijdens de taak zich ook generaliseert naar sociale interacties buiten de taak. Dit suggereert dat individuele verschillen in neuraal spiegelen bij jonge kinderen een belangrijke basis vormen voor gedragsafstemming en succesvolle sociale interactie.

In hoofdstukken 4 en 5 werd de sociale positie van kinderen in de klas onderzocht. Hoofdstuk 4 beschrijft een methodologisch sociometrisch onderzoek in kleuterklassen waarvoor een computerversie werd ontwikkeld en vergeleken met de originele offline procedure. Aan kinderen werd gevraagd om voor elke klasgenoot te beoordelen of ze het leuk vonden om met haar of hem te spelen (ja, soms wel en soms niet, nee). Op basis van deze oordelen werd de voorkeur van alle klasgenoten voor elk kind in de klas berekend. Deze scores werden ook omgezet naar een sociale status (geaccepteerd, verworpen, controversieel, genegeerd, of gemiddeld). In de originele methode verdeelden kinderen foto's van klasgenoten over drie bakjes behorende bij de drie antwoordcategorieën. In de computerversie werden de foto's op de computer gepresenteerd en klikten kinderen op één van drie smileys die correspondeerden met de antwoordcategorieën. Beide methodes leverden vergelijkbare verdelingen van continue scores en statusgroepen op en slechts kleine verschillen in correlaties tussen de drie antwoorden. Er waren geen verschillen in de interne consistentie van de oordelen die over het algemeen hoog was, wat aangeeft dat er homogene constructen werden gemeten. Er waren kleine verschillen in interbeoordelaar betrouwbaarheid die over het algemeen laag was, wat wijst op normale individuele verschillen in sociale voorkeur voor andere personen. De computerversie leverde interessante aanvullende gegevens op voor verdere analyse, zoals over antwoordtendenties. De computerversie is daarmee een veelbelovend instrument voor sociometrische meting in kleuterklassen die vergelijkbare resultaten oplevert als de offline procedure, maar daarnaast ook meer informatie over bijvoorbeeld antwoordtendenties. Deze methode biedt dus nieuwe mogelijkheden voor toekomstig onderzoek en verdere verbeteringen van sociometrie met jonge kinderen, bijvoorbeeld middels visuele en auditieve ondersteuning. Deze aanpassingen kunnen de computermethode mogelijk nog geschikter maken voor jonge kinderen of kinderen met speciale ondersteuningsbehoeften.

Hoofdstuk 5 beschrijft een longitudinaal onderzoek waarin we onderzochten of gedragsafstemming en de kwaliteit van sociale interacties in de peutertijd de sociale positie van kinderen op school voorspelden. We vonden dat peuters die tijdens de coöperatietaak meer affiliatief en minder antagonistisch gedrag vertoonden later op school meer geliefd waren bij hun leeftijdsgenoten. Vroege gedragsafstemming voorspelde de latere sociale positie van kinderen in de klas niet. De voorspellende waarde van de kwaliteit van sociale interacties tijdens de peutertijd is vooral bijzonder interessant omdat dit gedrag niet stabiel was. Kinderen die relatief veel affiliatief gedrag vertoonden toen zij twee jaar oud waren, waren niet perse de kinderen die veel affiliatief gedrag vertoonden op drie- of vierjarige leeftijd. De hoge correlatie tussen het gedrag van de twee kinderen die samen speelden toonde aan dat jonge kinderen hun gedrag flexibel aanpassen aan verschillende leeftijdsgenoten.

Ondanks de grote variabiliteit in interactiekwaliteit in verschillende situaties lopen peuters met een gedragsprofiel van weinig affiliatief gedrag en veel antagonistisch gedrag een verhoogd risico op een lage sociale positie later in de klas. De voorspellende waarde van de interactiekwaliteit voor de sociale positie in de klas was al duidelijk op de leeftijd van 28 maanden. Individuele verschillen in interactiekwaliteit op die leeftijd behoren dus mede tot de vroege basis van de sociale voorkeur van kinderen door hun latere klasgenoten.

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Curriculum Vitae

Hinke Marleen Endedijk was born in Zevenaar, the Netherlands, on November the 5th 1984. In September 2003, she started studying Pedagogical and Educational Sciences at the Radboud University, Nijmegen. Hinke obtained a Bachelor's degree in August 2006, received the clinical NVO-qualification in July 2008, and graduated from the Research Master Behavioural Science (Bene Meritum) in February 2010. In the meantime, Hinke worked with adolescents with Autism at the Leo Kannerhuis from July 2006 until February 2009, and held a teaching position from October 2009 on at the Radboud University, Nijmegen. Hinke started her PhD research in August 2010 at the Radboud University, Nijmegen, both at the Donders Institute for Brain, Cognition and Behaviour (the BabyBRAIN group) with Sabine Hunnius and Harold Bekkering, and the Behavioural Science Institute with Toon Cillessen. In addition to her PhD, Hinke continued teaching and supervising students and was statistical consultant, for which she obtained the University Teaching Qualification (UTQ, in Dutch BKO) in December 2014. After finishing her PhD, Hinke continued research and teaching as a Post Doc in the field of Pedagogical Sciences in the Youth and Family group of Susan Branje at Utrecht University.

Donders Graduate School for Cognitive Neuroscience

For a successful research Institute, it is vital to train the next generation of young scientists. To achieve this goal, the Donders Institute for Brain, Cognition and Behaviour established the Donders Graduate School for Cognitive Neuroscience (DGCN), which was officially recognised as a national graduate school in 2009. The Graduate School covers training at both Master's and PhD level and provides an excellent educational context fully aligned with the research programme of the Donders Institute.

The school successfully attracts highly talented national and international students in biology, physics, psycholinguistics, psychology, behavioral science, medicine and related disciplines. Selective admission and assessment centers guarantee the enrolment of the best and most motivated students.

The DGCN tracks the career of PhD graduates carefully. More than 50% of PhD alumni show a continuation in academia with postdoc positions at top institutes worldwide, e.g. Stanford University, University of Oxford, University of Cambridge, UCL London, MPI Leipzig, Hanyang University in South Korea, NTNU Norway, University of Illinois, North Western University, Northeastern University in Boston, ETH Zürich, University of Vienna etc.. Positions outside academia spread among the following sectors: specialists in a medical environment, mainly in genetics, geriatrics, psychiatry and neurology. Specialists in a psychological environment, e.g. as specialist in neuropsychology, psychological diagnostics or therapy. Positions in higher education as coordinators or lecturers. A smaller percentage enters business as research consultants, analysts or head of research and development. Fewer graduates stay in a research environment as lab coordinators, technical support or policy advisors. Upcoming possibilities are positions in the IT sector and management position in pharmaceutical industry. In general, the PhDs graduates almost invariably continue with high-quality positions that play an important role in our knowledge economy.

For more information on the DGCN as well as past and upcoming defenses please visit: http://www.ru.nl/donders/graduate-school/donders-graduate/

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