

Little Chameleons

An Investigation into the Development
and Mechanisms of Behavioral Mimicry



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Johanna E van Schaik

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Mechanisms of Behavioral Mimicry

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Johanna Elizabeth van Schaik
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Promotoren:

Prof. dr. H. Bekkering

Prof. dr. I. Toni

Copromotor:

Dr. S. Hunnius

Manuscriptcommissie:

Prof. dr. A.H.N. Cillessen

Prof. dr. B. Elsner (Universit t Potsdam, Duitsland)

Dr. H. Over (University of York, Verenigd Koninkrijk)

CONTENTS

<i>Chapter 1:</i> General Introduction	7
<i>Chapter 2:</i> Evidence for Nonconscious Behavior-Copying in Young Children	31
<i>Chapter 3:</i> Little Chameleons: The Development of Social Mimicry During Early Childhood	45
<i>Chapter 4:</i> Modulating Mimicry: The Roles of Inhibitory Control and Social Understanding in 5-Year-Olds' Behavioral Mimicry	61
<i>Chapter 5:</i> Young Children's Motor Interference is Influenced by Novel Group Membership	83
<i>Chapter 6:</i> Measuring Mimicry: General Corticospinal Facilitation During Naturalistic Behavior Observation	99
<i>Chapter 7:</i> General Discussion	117
References	135
English Summary	157
Nederlandse Samenvatting	165
Curriculum Vitae	173
Publications	177
Acknowledgements	181
Donders Graduate School for Cognitive Neuroscience	187

Chapter 1

General Introduction

THE CHAMELEON EFFECT

Although we might not be aware of it, our social interactions are characterized by a tendency to copy one another's behaviors and postures. In early explorations of this phenomenon, researchers transcribed interaction partners' behaviors and postures over time using video recordings of real social interactions. These timelines revealed that a speaker's behaviors and postures were at times mirrored by the listener (Kendon, 1970). Moreover, instances of postural mirroring were related to the social dynamics of the interactions, which was often measured as rapport: the interaction partners' subjective experience of the interaction typified by mutual attentiveness, friendliness and a coordinated feeling (Tickle-Degnen & Rosenthal, 1990). For example, during a therapy session, postural mirroring between therapist and client increased over time and was related to their rapport (Charny, 1966). Similarly, higher levels of postural mirroring during interactions were related to higher levels of questionnaire-reported rapport between instructors and students during college seminars (LaFrance, 1979; LaFrance & Broadbent, 1976).

These observations were succeeded by naturalistic experiments with the aim of testing this relationship between posture sharing and social dynamics. In an in situ experiment, when counselors assumed the arm and leg postures of their high school student clients they were perceived as significantly more empathic by their clients than when they ensured that their posture was non-congruent (Maurer & Tindall, 1983). In another ecological approach, the social dynamics of the interaction were manipulated while the naturally occurring behaviors of naïve interaction partners were measured. Here, LaFrance (1985) found that college student dyads who were instructed to cooperate with another dyad showed higher postural mirroring as a group, while dyads who were competing with the other dyad showed more within-dyad mirroring (LaFrance, 1985). Thus, copying during natural interactions increases interpersonal rapport and, fittingly, the amount of copying differs depending on the social context (i.e. the desired level of rapport).

In 1999, Chartrand and Bargh published a set of controlled experiments measuring this propensity to copy the behaviors of others and the social consequences thereof. In a shift away from the mirroring of postures, more transient yet repetitive behaviors were used. They tested whether participants would mirror the face rubbing, foot shaking, and smiling of confederates. Following a one-minute baseline during which the participant was left alone in the waiting room, the participant performed a photograph description task with two confederates, one after the other. In this task, interaction partners took turns

describing a photograph to the other. One of the confederates tapped their foot during the interaction while the other rubbed their face. Additionally, one of the confederates smiled throughout the session while the other did not. Participants' performance of these target behaviors was quantified as the number of times performed per minute of interaction. Analyses with individual participants' baseline behavior rates as covariates showed that participants smiled significantly more when interacting with the smiling confederate than they did with the non-smiling confederate and performed each behavior more often while interacting with the confederate performing that behavior than with the other confederate. Interestingly, when later asked about the experiment, participants did not report noticing or copying these mannerisms. Hence, Chartrand and Bargh (1999) provided the first experimentally controlled evidence that individuals mimic their interaction partners' behaviors and facial expressions outside of awareness. They referred to this tendency to mimic as the 'chameleon effect'. Humans, they proposed, match their behaviors to the current social environment just as a chameleon might change the color of its skin to blend in with the physical surroundings (Chartrand & Bargh, 1999). A myriad of investigations into the chameleon effect have since ensued.

Behavioral Mimicry

While in its broadest sense 'mimicry' can refer to various forms of implicit copying (Chartrand & van Baaren, 2009) – including accents (Giles & Powesland, 1975 in Lakin, Jefferis, Cheng, & Chartrand, 2003), co-speech gestures (Holler & Wilkin, 2011), and facial and emotional expressions (Dimberg, 1982; Hatfield, Cacioppo, & Rapson, 1994; Lundqvist, 1995) – the present thesis focuses on behavioral mimicry (Chartrand & Lakin, 2013; Lakin, 2013). This form of mimicry encompasses the examples from the aforementioned experiments, including posture, manual and pedal behaviors, and other motor behaviors, such as head movements. These behaviors have in common that they are in themselves meaningless and non-valenced. Although arguably any behavior can be communicative in a specific setting, these behaviors are not functionally related to the explicit nature of the examined interactions (e.g. rubbing your hands over one another during a conversation over dinner might be mimicked by your fellow diners). Hence, they are neither cultural gestures (e.g. waving to the person seated at the end of the table) nor object-directed actions with the goal of achieving an end state (e.g. shaking a pepper shaker to season your meal).

Mimicking. Following Chartrand and Bargh (1999), experimental mimicry paradigms have followed a general formula. Typically, a behavioral mimicry

experiment entails a participant interacting with a confederate who repeatedly but surreptitiously performs a target behavior. Either the particular social context of the interaction is manipulated to test its effect on mimicry or participants' mimicry is related to a third external measure. Ideally, a baseline measure is used to establish whether the participant performed the behaviors more during the experimental interactions than she might otherwise do (Lakin, 2013). Oftentimes participants are subjected to a funneled debriefing at the end of the experiment (e.g. Chartrand & Bargh, 1999) and only the data of participants who did not notice the behaviors is included in the final analyses (e.g. Lakin, Chartrand, & Arkin, 2008).

Given the link between behavioral mimicry and rapport found in the early observational studies, numerous experiments have investigated under which circumstances participants enhance or suppress their behavioral mimicry. In a set of studies, Lakin and Chartrand (2003) hypothesized that mimicry would increase in situations in which individuals wanted to affiliate with their interaction partner. In the first study, participants viewed a video of a confederate who was performing clerical tasks and surreptitiously touching her face. Participants who had been told they would later need to interact with her before watching the video, and thereby had reason to affiliate her, performed these behaviors significantly more often than participants who were not told this (note though that there was no baseline measure). In a second study, the authors let participants, who had or had not received an affiliation goal first, experience being treated in an unfriendly or friendly manner during an online interview. Subsequently, participants interacted with a second confederate, who shook her foot throughout the interaction. In an analysis including a baseline measure as a covariate, participants with an affiliation goal mimicked the second confederate's foot shaking significantly more if they had been treated in an unfriendly manner than in a friendly one. Also, the second confederate, blind to condition, liked participants more and reported higher rapport after interactions with affiliation-goal participants in the unfriendly condition than in the friendly condition (see also the following section). The authors concluded that mimicry served as a means to affiliate and stimulate liking (Lakin & Chartrand, 2003).

In the above study, mimicry was more evident after a failure to affiliate with a peer. This ostracism-like effect was further tested in a study in which participants were included or excluded during a digital ball passing game called Cyberball. In a subsequent live interaction with a foot-shaking confederate, participants displayed this behavior for a greater percentage of time if they had been ostracized during Cyberball than if they had been included (with baseline included as a covariate; Lakin et al., 2008). This finding provides further support for

an affiliation role of mimicry; the ostracism that participants experienced during the ball passing game is thought to have threatened participants' need to belong (Lakin & Chartrand, 2005; Lakin et al., 2008; Leary, 2001). Humans have a need to frequently interact with others in positive affiliative interactions and form lasting meaningful relationships. This motivation guides individuals to form relationships and social groups (Baumeister & Leary, 1995). As a result, exclusion from specific relationships threatens an individual's need to belong (to that social relationship) more than from others and thereby might trigger more affiliative behaviors, such as mimicry (Lakin et al., 2008).

This pattern was identified in Lakin and colleague's (2008) second study. Female participants were first informed of the gender of their fellow players and then ostracized during a game of Cyberball. In a subsequent interaction, participants who had been ostracized by fellow females mimicked female confederates (i.e. in-group members) significantly more than male confederates (i.e. non-in-group members). There were no differences in mimicry of in-group and non-in-group confederates in the sample that had been excluded by non-in-group Cyberball players. Even though they had been excluded from their in-group, these participants reported higher belonging to their in-group than participants excluded by non-in-group members, and belongingness significantly predicted mimicry in these participants (Lakin et al., 2008). These two studies (Lakin & Chartrand, 2003; Lakin et al., 2008) demonstrate that individuals mimic others more when they want to affiliate with them and an inability to affiliate, such as through being ostracized, enhances mimicry. Hence, mimicry seems to be a dynamic and specific means of pursuing affiliation.

However, if mimicry communicates affiliation, it should be absent when one does not want to affiliate, such as while interacting with an out-group member. Yabar and colleagues (2006) demonstrated this by comparing behavior rates during the experimental session with those from a baseline such that absolute increases (i.e. mimicry) or reductions (i.e. negative mimicry) could be tested. Participants viewed videos of a neutral individual and an out-group member. After seemingly studying a picture for one minute (serving as a baseline period), the model in the video started to describe the picture while rubbing her face. Participants' face rubbing was coded and the percentage of time spent rubbing during the baseline period was subtracted from that of the experimental period. A significant difference in face rubbing between the neutral model and out-group model was reported. Whereas participants performed the behaviors significantly more when demonstrated by the neutral model, indicating mimicry, the authors reported a trend towards negative mimicry: a decrease in behaviors relative to the baseline when performed by an out-group member. Hence, the chameleon

effect is not a necessary tendency in all interactions (Yabar, Johnston, Miles, & Peace, 2006); instead, humans selectively mimic to blend in with certain social environments, like those filled with in-group members, but refrain from mimicking in social environments for which they do not hold affiliation goals (cf. Chartrand & Bargh, 1999).

The term 'blending in' implies that mimicking also communicates similarity. Some evidence for this comes from a study in which participants interacted with two confederates; one shared the participant's opinions on a holiday destination and the other disagreed. When controlling for a baseline measure taken from the start of the interaction, participants shook their foot more when the similar-preference confederate did so than when the similar-preference confederate rubbed their arm (though this mimicry effect was not found in participants' arm rubbing; van Swol & Drury, 2006). Interpreting this finding in combination with the ostracism and group effects on (negative) mimicry suggest that in the context of social interactions, similarity and affiliation are closely intertwined. Indeed, humans tend to prefer similar others and similarity is a marker of social groups (Haun & Over, 2015). It could thus be said that mimicry conveys, "I (am) like you".

Being mimicked. For mimicry's message of "I (am) like you" to be effective, it must also be the case that we like people who mimic us. Such a consequence of being mimicked was suggested by the initial investigations into the relationship between mimicry and rapport (e.g. Maurer & Tindall, 1983). Chartrand and Bargh (1999) went on to test this in their laboratory setup. During a photograph description task, confederates either did or did not mimic the natural mannerisms and postures of participants. Participants who were mimicked reported liking the confederate more and experienced a smoother interaction than participants who were not mimicked. Interestingly, participants did not report noticing being copied (Chartrand & Bargh, 1999). This positive effect of being mimicked was replicated in a study in which digital avatars either mimicked participants' head postures at a delay of four seconds or used the head postures of a previous participant. Mimicking avatars, though their mimicry was not detected, were rated as being more likeable and realistic and possessing more positive traits (as measured in one composite score) than the yoked avatars (Bailenson & Yee, 2005). Hence, mimicry seems to be an effective affiliation tool, as being mimicked increases liking (Chartrand & Lakin, 2013).

Experiments testing the effects of being mimicked further highlight the typical presence of mimicry during affiliative interactions. When participants were not mimicked during a social interaction, markers of stress increased, an effect mediated by the extent to which participants reported a need to belong (Kouzakova,

van Baaren, & van Knippenberg, 2010). Such experiments typically exclude participants who detected the mimicry manipulation (e.g. Chartrand & Bargh, 1999; Kouzakova et al., 2010). Investigating this situation, though, indicates that when mimicry is too obvious, the positive effects diminish (Bailenson, Yee, Patel, & Beall, 2008; Leander, Chartrand, & Bargh, 2012). Thus, there seems to be a typical level of mimicry during casual, affiliative, social interactions.

Accordingly, and further reflective of the early studies, observing (an absence of) mimicry provides information as to the rapport of the interaction. For example, participants who observed staged interactions between a therapist and a client rated interactions in which the therapist mimicked the client as having higher rapport than interactions without mimicry (Trout & Rosenfeld, 1980). Relatedly, participants rated individuals who mimic unkind individuals as less competent than individuals who do not mimic an unkind person and individuals who do mimic a kind person (Kavanagh, Suhler, Churchland, & Winkielman, 2011). This visibility of the affiliative effect of mimicry to observers further suggests that mimicry is a commonplace and essential, albeit implicit, feature of positive social interactions.

Overall, behavioral mimicry occurs during affiliative social interactions and leads to increased liking and rapport. It occurs without us being explicitly aware of its presence, as evident from live interaction experiments (Chartrand & Bargh, 1999; Lakin et al., 2008) and video-based designs (Lakin & Chartrand, 2003; Yabar et al., 2006). As an affiliation means, it can be enhanced through increasing our desire to affiliate or to be similar to our interaction partners, for example by increasing liking or by threatening our belonging to a social group. Although the aforementioned studies concerned primarily English-speaking Western cultures, behavioral mimicry has also been tested in continental European samples (e.g. van Baaren, Fockenberg, Holland, Janssen, & van Knippenberg, 2006) and Japanese participants (though this sample had lived at most four years in the USA; van Baaren, Maddux, Chartrand, de Bouter, & van Knippenberg, 2003).

Given the affiliative function and the seeming prevalence of this implicit social interaction behavior in adults, it is surprising that we still know very little about where mimicry comes from. When does it emerge? Which developmental mechanisms are involved? And how does the brain produce this implicit social behavior? Through investigating both the development and neurocognitive basis of behavioral mimicry, we will not only come to a better understanding of mimicry as a behavioral phenomenon, but we can also use this social behavior as a window into social development and the social brain. As an implicit means of affiliation, children's (selective) use of mimicry can reveal their understanding of and sensitivity to social interaction contexts. Similarly, identifying the neuro-

cognitive processes that lead to mimicry might further shed light on our implicit processing of the social environment.

The present thesis explores the development of social behavioral mimicry and the neurocognitive processes underlying it. In the following two sections, I outline what is known about the development and neurocognitive foundations of copying behaviors to gain insight into the possible bases of mimicry and to highlight what remains unknown.

THE DEVELOPMENT OF SOCIAL BEHAVIOR COPYING

Young children's play is riddled with copying behaviors (Eckerman & Peterman, 2004). These instances of copying can take many forms but have in common that the observation of an individual's movement is causally related to a similar movement in the observer (Heyes, 2001).

Development of Copying

An often-cited form of copying behavior is neonatal imitation. Several experiments reported that newborn infants (Meltzoff & Moore, 1983) and infants of a few weeks old (Meltzoff & Moore, 1977) imitate facial and manual actions modeled by an adult. These findings have been cited by the mimicry literature as evidence that mimicry is present from birth (Lakin, 2013; Lakin et al., 2003), though criticism of these effects has also been considered (Chartrand & Bargh, 1999; Chartrand & van Baaren, 2009). This criticism has concerned the statistical methodology as well as failed replications and alternative explanations (Abravanel & Sigafos, 1984; Anisfeld, 1991; Anisfeld, Masters, Jacobson, & Kagan, 1979; Jones, 1996, 2006a). After over 80 replication studies with mixed results and limited sample sizes (Heyes, 2016), a recent longitudinal study conducted with 106 1- to 9-week-old infants provided fairly definitive evidence against neonatal imitation (Oostenbroek et al., 2016). Oostenbroek and colleagues (2016) found that infants were as likely to produce the target behaviors in response to models demonstrating these behaviors as they were to models performing other behaviors. Thus, it is unlikely that infants can copy behaviors from birth (Heyes, 2016).

Instead, infants are first able to copy the behaviors they observe others perform near the end of their first year of life and the complexity of copying increases with age. In a cross-sectional study of infants of 6 to 20 months old, Jones (2007) compared infants' behavior rates while a parent demonstrated the target behavior with the spontaneous production of the target behavior during

the parent's demonstration of another behavior. At 8 and 12 months of age, infants demonstrated reliable imitation of vowel vocalizations. At 12 months, infants reliably imitated action-effect pairs, such as clapping hands together to make sound, and a cultural gesture, namely waving bye-bye. It was not until 16 to 18 months of age that infants imitated actions without salient effects, such as putting a hand on their head (Jones, 2007). This earlier acquisition of interesting action-effect associations was also reported in a longitudinal study with 6- to 15-month-olds. Infants started imitating transitive actions with visual or auditory effects, such as stacking blocks or squeezing a rubber duck to make a sound, between 9 and 12 months and imitation rates increased again from 12 to 15 months of age (Abravanel, Levan-Goldschmidt, & Stevenson, 1976). Indeed, the preference for action-effect imitation persists in the second year of life, as shown in an experiment with 12- and 18-month-olds; after observing a sequence of three actions of which one or none had a salient effect, infants preferentially imitated the action-effect pair and did so quicker and more frequently than actions not coupled with a salient effect (Hauf, Elsner, & Aschersleben, 2004). Notably, there is limited evidence for infants imitating intransitive gestural behaviors like those of adult mimicry studies (e.g. head shaking; Abravanel, Levan-Goldschmidt, & Stevenson, 1976). This gradual emergence of imitation suggests that multiple motor, social, cognitive and motivational components play a role in the development of copying (Jones, 2009) and that infants' initial copying is largely constrained to salient action-effect associations (Elsner, 2007; Paulus, 2014).

Beyond a difference in what is being copied (i.e. action-effect pairs versus meaningless mannerisms), this evidence for early copying differs from adult behavioral mimicry in the circumstances under which it occurs. Whereas adult mimicry is typified by its occurrence in situations in which participants' primary focus is the task at hand and the demonstrated mimicry behaviors are unrelated to this task (van Baaren, Janssen, Chartrand, & Dijksterhuis, 2009), in developmental studies the copying behavior is the focus of the interaction. Often, infants are encouraged to copy demonstrated behaviors (e.g. Jones, 2007) and are rewarded when they indeed do so (Heyes, 2013). Only a handful of studies have investigated (semi-)implicit instances of copying resembling adult mimicry. The investigated behaviors entail the notoriously contagious yawn (Anderson & Meno, 2003; Helt, Eigsti, Snyder, & Fein, 2010; Millen & Anderson, 2011) and, more recently, facial expressions (Deschamps, Schutte, Kenemans, Matthys, & Schutter, 2012; Geangu, Quadrelli, Conte, Croci, & Turati, 2016).

On a subjective level, most adults would likely agree that yawning is highly contagious. In addition to the many hypotheses regarding the physiological

functions of yawning, this contagious characteristic has led to a hypothesized communicative function, which some argue is the most probable function of yawning (Guggisberg, Mathis, Schnider, & Hess, 2010). Still, evidence for the presence of contagious yawning in children is limited to a handful of studies. Using live (Helt et al., 2010), video (Anderson & Meno, 2003), and photographic models (Millen & Anderson, 2011), evidence for children contagiously yawning was found from the age of 4-5 years onward, while the youngest tested age was 12 months. This developmental trajectory has been interpreted as evidence that contagious yawning depends on social developmental factors (Guggisberg et al., 2010). In support of a relationship with social development, studies with 6- to 15-year-old typically developing children and children with ASD demonstrate that children with ASD are less susceptible to contagious yawning (Giganti & Ziello, 2009; Helt et al., 2010; Senju et al., 2007). Extending these findings, it could hence be the case that other forms of behavioral mimicry also develop during early childhood, depending on factors of social development. However, while contagious yawning might be a textbook example of behavioral mimicry on a subjective level, the physiological functions of yawning complicate the communicative argument of the behavior. Indeed, yawning and its (non)social function(s) are still a matter of much debate (Gallup, 2011; Guggisberg, Mathis, Schnider, & Hess, 2011).

In another line of research, recent advances have allowed for the application of relatively child-friendly electromyography (EMG) electrodes to measure facial mimicry in children. Adult studies have shown that corresponding facial muscle activation can be recorded upon presentation of a facial expression (Hess, Houde, & Fischer, 2014; Seibt, Mühlberger, Likowski, & Weyers, 2015). This technique has been successfully utilized to study facial mimicry in 6- to 7-year-old children (Deschamps et al., 2012) and recently even in 3-year-olds (Geangu et al., 2016). As is the case for contagious yawning, differences have been identified between typically developing children and those with social developmental disorders. In several samples of children ranging from 6 to 13 years of age, children with ASD or disruptive behavior disorder displayed decreased facial mimicry and slower mimicry responses (Beall, Moody, McIntosh, Hepburn, & Reed, 2008; De Wied, van Boxtel, Posthumus, Goudena, & Matthys, 2009; De Wied, van Boxtel, Zaalberg, Goudena, & Matthys, 2006; Deschamps, Coppes, Kenemans, Schutter, & Matthys, 2015; Oberman, Winkielman, & Ramachandran, 2009). Such findings again suggest an influence of social development on behavior copying. Moreover, these studies demonstrate the potential clinical relevance of investigating affiliative social copying behaviors during early child-

hood, starting with the prerequisite of first understanding the typical development of these behaviors.

However, while the facial mimicry studies best match adult mimicry in that they involve non-instructed instances of copying, facial mimicry differs from behavioral mimicry in three fundamental ways. First, the nature of what is being copied is not per definition non-valenced. Though not always the case, facial expressions communicate emotions and these can further convey appraisals such as affiliation and dominance (Hess et al., 2014; Seibt et al., 2015). Second, facial mimicry as measured with EMG entails reactions that occur in the order of milliseconds (Dimberg & Thunberg, 1998). Although often defined as occurring within a few seconds (Lakin, 2013), behavioral mimicry studies in adults rarely report the time window in which a participants' behavior is still scored as mimicry. Likewise, the duration of the recorded EMG responses lasts a few seconds (Dimberg & Thunberg, 1998), while behavioral mimicry can entail postures that are maintained throughout an interaction. Third, the use of EMG measurement indicates that the reported facial mimicry occurs on the level of subtle muscle contractions. These therefore might not always be visible to interaction partners (Seibt et al., 2015). Behavioral mimicry, on the other hand, is visually coded, meaning that behaviors must be detectable by the naked eye. Thus, the presence of facial mimicry in young children might be distinct from children's use of non-valenced, slow and overt behavioral mimicry during social interactions. Nonetheless, the adult literature presents many parallels between the social consequences of facial and behavioral mimicry (Chartrand & van Baaren, 2009; Hess et al., 2014; Seibt et al., 2015), suggesting that the emergence of social behavioral mimicry might also occur during early childhood.

Social Copying

The ontogeny of copying is inherently social and positively valenced (Heyes, 2013). Infants spend the majority of their waking hours in face-to-face interactions during which parents repeatedly copy their infant's behaviors (Jones, 2006b; Kokkinaki & Kugiumutzakis, 2000; Užgiris, Benson, Kruper, & Vasek, 1989). In turn, when an infant is the one to copy, mothers have been shown to reward this imitation with smiles and vocal encouragement (Pawlby, 1977 in Ray & Heyes, 2011). This seems to promote copying, as infants who were rewarded for imitation more frequently also imitated more types of behaviors and did so more often (Waxler & Yarrow, 1975). Thus, copying is already associated with positive affiliative interactions during early development.

This social connotation of copying continues to be evident during toddlers' interactions with others. During peer interactions, imitative acts, such as perform-

ing the same action on the same toy, increase considerably in occurrence from 16 months to around 3 years of age (Eckerman, Davis, & Didow, 1989). In these interactions, imitation is the most common means of initiating interactions and social play, and many of toddlers' spontaneous games are imitative in nature (Eckerman et al., 1989; Lubin & Field, 1981; Nadel, 2002). Yet, imitation during natural peer interactions decreases starting from 3 up until 11 years of age (Abramovitch & Grusec, 1978; Grusec & Abramovitch, 1982; Lubin & Field, 1981). As children age, they likely increasingly rely on other affiliation strategies instead of explicit imitation (Abramovitch & Grusec, 1978; Nadel, 2002). Importantly, even though the frequency of explicit imitative acts decreases with age, peer imitation remains socially sensitive across childhood, with dominant children being copied most (Abramovitch & Grusec, 1978; Grusec & Abramovitch, 1982).

During adult-child interactions, children's imitation is also sensitive to social dynamics (Užgiris, 1981). In over-imitation paradigms an adult demonstrates a set of novel actions on a novel toy, some of which are causally related to an end-state and others of which are not (Horner & Whiten, 2005; Lyons, Young, & Keil, 2007). Modulations of the social dynamics in which the task occurs have demonstrated that toddlers' imitation in these tasks can be guided by affiliation or similarity goals (Over & Carpenter, 2012). For example, 2-year-olds copy adult models more faithfully when they are responsive (e.g. live or via CCTV) than when they cannot provide interactive feedback (e.g. via a video; Nielsen, Simcock, & Jenkins, 2008). Similarly, when 2-year-olds played an imitative game with a model prior to an over-imitation task they were more likely to imitate faithfully than if they had interacted with the model in a less social way by playing a puzzle-matching game or barely interacted with the model by drawing pictures. Interestingly, in this study, 4-year-olds were more likely to imitate faithfully than 2-year-olds and they did so across these conditions (Yu & Kushnir, 2014). Correspondingly, in another study, 4-year-olds' imitation was sensitive to the presence of the demonstrator, as they imitated more faithfully if the over-imitation model was still in the room than if she had left (Nielsen & Blank, 2011). Thus, young children's imitation seems to become increasingly sensitive to a goal to affiliate in general. Indeed, as opposed to natural instances of explicit peer imitation, over-imitation rates have been reported to significantly increase with age, even into adulthood (Marsh, Ropar, & Hamilton, 2014; McGuigan, Makinson, & Whiten, 2011). This developmental increase suggests that social understanding increasingly plays a role in these explicit imitative contexts.

Further support for affiliative over-imitation comes from a conceptual replication of the Lakin and colleagues (2008) ostracism mimicry study. In the develop-

mental paradigm, 5- to 6-year-olds were first assigned to the yellow group and made to think they shared several preferences with other yellow group members. They then played Cyberball with in-group or out-group members during which they were included or ostracized. Subsequently, they observed a video of an in- or out-group member performing a task with several arbitrary steps. There was a main effect of Cyberball condition, with ostracized children imitating more faithfully than included children. Post hoc analyses performed separately within the in-group condition and the out-group condition indicated that this effect was only present in children excluded by their in-group (Watson-Jones, Legare, & Whitehouse, 2016). Taken together, like adults' behavioral mimicry, children's social imitation is used to communicate similarity and affiliation (Over & Carpenter, 2012; Užgiris, 1981).

Additional evidence for the social communicative function of imitation during early childhood comes from two further lines of research. The first is similar to the absence of or even negative mimicry of out-group members found in adults (Yabar et al., 2006). Oostenbroek and Over (2015) showed two methods of turning on a light, with the elbow or with two hands pressed together. Either an out-group member or a neutral-group member subsequently demonstrated one of these two methods. Significantly more 4- and 5-year-olds turned the light on using the contrasting (i.e. not demonstrated) method in the out-group condition than the neutral-group condition (Oostenbroek & Over, 2015). The second line of research reflects the importance of nonverbal behavior in third-person observations of interactions, as also found in adults (e.g. Kavanagh et al., 2011). After observing an adult model imitate one of two other adults in several ways, a greater proportion of 5-year-olds, but not 4-year-olds, reported that the imitating model liked the person she imitated more than the other person. The majority of these children explained their choice based on the imitative behavior of the target model (Over & Carpenter, 2015). Hence, although the type of social imitation studied thus far in children differs from behavioral mimicry in its explicit and transitive nature, similar social sensitivities and functions of copying behavior are evident and become increasingly influential during early development.

Social-Cognitive Development

As reviewed above, children use copying to establish interactions with peers and adults (e.g. Eckerman et al., 1989; Waxler & Yarrow, 1975) and affiliate with their interaction partners and social groups (e.g. Watson-Jones et al., 2016). In addition to these social functions, copying also serves a nonsocial learning function, allowing children to learn how to use new tools or perform new actions (Over & Carpenter, 2012, 2013). This array of functions has led many scholars

to suggest that copying plays a fundamental role in early social-cognitive development (Jones, 2009; Meltzoff & Williamson, 2010; Over & Carpenter, 2012; Paulus, 2014). Yet, arguably, social-cognitive development and the development of imitation are likely mutually interdependent; while in some situations copying fosters novel social interactions that develop social understanding, in other situations a certain level of social understanding and behavioral control is needed in order for a child to amplify or prevent their copying behavior in a socially sensitive manner. Hence, in the pursuit of behavioral mimicry, certain advances in social understanding and behavioral control are likely necessary contributors to its development.

The term social understanding is used here in a broad sense as a marker of a child's performance on social perception tasks as well as her concepts of relationships and comprehension of social norms. As such, social understanding can be seen as a dynamic product of social interaction experiences during development (Carpendale & Lewis, 2004). A widely studied component of social understanding is social perspective taking. These tasks typically assess a child's ability to understand that other individuals can perceive a situation from a different perspective, can hold knowledge that is outdated or contradicting the child's current knowledge, and can have different emotional states or intentions. Performance on such theory of mind tasks indicate that a basic level of this understanding is present in 2-year-olds and that it advances rapidly through early childhood (Tahiroglu et al., 2014).

Understanding of interpersonal characteristics and social norms similarly show marked increases during early childhood. For example, similarity already affects toddlers' novel object or toy preferences, as they tend to choose items endorsed by individuals who shared earlier preferences with the child (Fawcett & Markson, 2010a; Gerson, Bekkering, & Hunnius, 2017). Three-year-olds are further sensitive to social or group markers of similarities, such as gender, age, and physical appearance (Fawcett & Markson, 2010b; Shutts, Banaji, & Spelke, 2010). Furthermore, children are even sensitive to arbitrary novel-group boundaries, with children as young as 3.5 years old explicitly preferring novel in-group members over out-group members (Richter, Over, & Dunham, 2016). This preference strengthens and by 5-6 years of age expands to encompass an in-group bias in both reasoning about whether an individual would perform positively-valenced behaviors and memory of who was said to have performed valenced behaviors (Dunham, Baron, & Carey, 2011). Additionally, 5- to 6-year-olds reason about different types of groups, acknowledging that friend groups like, share with, and are loyal to one another, while people who look like one another are more similar with respect to preferences and common knowledge

(Plötner, Over, Carpenter, & Tomasello, 2016). Likewise, social norm understanding parallels this drastic increase from toddlerhood to early childhood. For example, while toddlers and young children acknowledge that sharing is important and fairly divide resources in certain circumstances, they also show biases in their sharing which last until middle childhood (e.g. Chernyak & Sobel, 2016; Smith, Blake, & Harris, 2013). In short, during early childhood, children begin to recognize the affiliative characteristics of relationships and importance of social norms.

The transition from toddlerhood to early childhood is also a time during which children's inhibitory control improves. Inhibitory control refers to the ability to regulate or prevent dominant behavior from becoming overt. A range of tasks indicate that between the ages of 2 and 6 children become increasingly able to inhibit certain responses either entirely or in favor of executing other responses (Carlson, 2005). Interestingly, in addition to contributing to performance on social perspective taking tasks (Carlson, Mandell, & Williams, 2004; Carlson, Moses, & Breton, 2002), inhibitory control might also be related to young children's ability to regulate their behavior during joint interactions (Meyer, Bekkering, Haartsen, Stapel, & Hunnius, 2015).

In summary, copying ability develops during children's first years of life. Early social interactions reward copying and copying continues to be rewarded by stimulating peer play in toddlerhood. During early childhood, spontaneous explicit imitation during peer interactions seems to decrease, but the social sensitivity of other instances of copying continues to increase. Over-imitation paradigms indicate that young children's behaviors are sensitive to social dynamics in similar ways as adults' mimicry. This ongoing development of social copying coincides with children's increasing social understanding during early childhood. Concurrently, improvements in inhibitory control help children regulate their social interaction behaviors. While no studies have investigated behavioral copying akin to adult mimicry paradigms, investigations of contagious yawning suggest that it emerges during the kindergarten years and continues to increase in prevalence throughout childhood. Taken together, there is no direct evidence of uninstructed behavioral mimicry during early childhood, but the increasing social sensitivity of copying behaviors during this time suggests that mimicry might be an emerging product of young children's social-cognitive development.

THE NEUROCOGNITIVE BASIS OF SOCIAL COPYING

Chartrand and Bargh's (1999) experimental investigation into behavioral mimicry was an extension of the social psychologists' work on the 'perception-behavior link'. They defined this link as the tendency to act in a similar way after having observed another individual's behavior. Following this reasoning, the authors expected that perspective taking would be positively related to behavioral mimicry, as participants who attended their interaction partners more would perceive their behaviors more and hence be more susceptible to the effect of perception on behavior. To test this, they had participants perform the photograph description task with a simultaneously foot-shaking and face-rubbing confederate and fill in a perspective taking scale. The subset of participants who scored above the sample median on perspective taking performed these behaviors significantly more often than those who scored below the sample's median (though note that no baseline measure was included; Chartrand & Bargh, 1999). The perception-behavior link has since been the cited mechanism of behavioral mimicry and the wealth of cognitive (neuro-)science evidence for perception-behavior mapping has been used in support of this explanation.

The notion that there is a link between the perception and execution of behaviors stems from decades of cognitive psychological theorizing and behavioral research (Greenwald, 1970; James, 1890; Prinz, 1990). Findings from an array of behavioral paradigms provide evidence for a common neurocognitive representation of perceiving and executing actions (Prinz, 1997). Furthermore, neurophysiological findings have shed light on the neural implementation of this overlap (di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992) and a great number of cognitive neuroimaging studies have since identified the specifics of this neural activity (Fadiga, Craighero, & Olivier, 2005; Fox et al., 2016; Molenberghs, Cunnington, & Mattingley, 2012). Developmentally, this coupling of perception and action likely develops as a product of (social) experience during early ontogeny (Del Giudice, Manera, & Keysers, 2009; Ferrari, Tramacere, Simpson, & Iriki, 2013; Heyes, 2010, 2013). Adult studies further demonstrate that perception-behavior mapping is modulated by the social context of interactions (Gutsell & Inzlicht, 2013; Kourtis, Sebanz, & Knoblich, 2010) and provide part of the neurocognitive basis of instructed imitation (Caspers, Zilles, Laird, & Eickhoff, 2010; Iacoboni, 2009; Molenberghs, Cunnington, & Mattingley, 2009). Together, the characteristics and social sensitivity of perception-behavior mapping support its role in producing this implicit imitative social behavior.

However, there is scarce evidence from which a causal role of a perception-behavior mapping system in producing behavioral mimicry can appropriately

be inferred (Hogeveen, Chartrand, & Obhi, 2015). In other words, very few neuroimaging studies have investigated behavior observation contexts comparable to those in which behavioral mimicry naturally occurs (see for an exception van Ulzen, Fiorio, & Cesari, 2013). Instead, the existent behavioral and neuroimaging experiments, which entail instructed imitation or explicit observation of simple actions, provide insight into the plausible brain basis of mimicry. The behavioral paradigms deliver a robust, easily applied measure through which the modulation of perception-behavior mapping by social factors (e.g. interaction partner's group membership) can be tested in both adults and young children. Additionally, neuroimaging studies present a more direct measure of social effects on perception-behavior mapping while allowing for passive observation, which better matches the circumstances under which mimicry occurs.

Response Compatibility Paradigms

Behavioral evidence for an overlapping representation of the perception and execution of action comes from response compatibility paradigms (RCPs). In these paradigms, participants need to perform one action while simultaneously observing either a congruent or an incongruent action. Participants' responses during incongruent conditions demonstrate interference, indicating that the processing of the incoming action perception overlaps with that of action execution. Two types of RCPs have demonstrated a social sensitivity in perception-behavior mapping: motor interference and automatic imitation.

In the motor interference task, participants make continuous, straight, back-and-forth arm or hand movements while observing the same type of movement in either a congruent or incongruent direction. Studies find that, during incongruent trials, participants' motion paths deviate in the direction of the incongruent stimulus. For instance, if a participant moves his arm along the horizontal axis, concurrently observing a model moving her arm in the vertical axis leads the left-to-right motion path of the participant to deviate upwards and downwards into this uninstructed axis (Blakemore & Frith, 2005; Kilner, Paulignan, & Blakemore, 2003; Kilner, Hamilton, & Blakemore, 2007). Although there is a spatial component to the task, spatial compatibility cannot fully explain the interference effects. In a variant of the task, participants observed either a straight vertical movement, or a curvilinear horizontal movement with the same endpoint of the participants' own straight horizontal movement. Both the horizontal curvilinear and vertical straight conditions caused interference in the participants' straight horizontal movements, despite the fact that the curvilinear movement's spatial endpoints were identical to the participants' (Roberts, Hayes, Uji, & Bennett, 2015).

What makes the motor interference task relevant for the present investigations into children's behavioral mimicry is its amicability to both social manipulations (Roberts, Bennett, & Hayes, 2016) and developmental adaptations. Two developmental studies have utilized a tablet computer adaptation of the motor interference task (Marshall, Bouquet, Thomas, & Shipley, 2010; Saby, Marshall, Smythe, Bouquet, & Comalli, 2011). Here, kindergartners were asked to draw back-and-forth in a predefined direction on the tablet using a stylus. Simultaneously, a stimulus video being displayed on the tablet showed a model moving her arm in either the congruent or incongruent direction. Four- to 5-year-olds were found to experience motor interference, as their drawings had higher deviations in the uninstructed axis during incongruent stimulus videos than congruent (Marshall et al., 2010; Saby et al., 2011). Moreover, the extent of interference experienced was modulated by whom the children were observing; children experienced greater interference when they observed a peer in the stimulus video than an adult and this was interpreted as a consequence of the models' social identities (i.e. a possible friend versus an adult; Marshall et al., 2010). Thus, in addition to demonstrating the feasibility of using motor interference tasks with children, these studies suggest that social modulation of perception-behavior mapping might already be evident in young children.

A second RCP, automatic imitation, requires participants to perform a particular movement, like opening the hand, at the sight of one cue and to make an opposing movement, closing the hand, in response to another cue. At the same time, participants see a photo or video of a congruent or incongruent action. Interference in participants' responses are evident in the slower reaction times during incongruent conditions than congruent conditions (Brass, Bekkering, & Prinz, 2001; Brass, Bekkering, Wohlschläger, & Prinz, 2000; Stürmer, Aschersleben, & Prinz, 2000). Automatic imitation is relevant for mimicry research because the imitative nature and unintentional occurrence that are characteristic of both automatic imitation and behavioral mimicry have led automatic imitation to be termed the laboratory version of mimicry (Heyes, 2011). Consequently, automatic imitation has been utilized as a proxy for mimicry in investigations into the possible mechanisms of this social behavior. In many ways, automatic imitation is advantageous because it is easily used in confined and controlled conditions, lending itself to neuroimaging setups (e.g. Wang, Newport, & Hamilton, 2011). Additionally, many of the social factors that influence behavioral mimicry have also been found to modulate interference effects (e.g. Hogeveen & Obhi, 2013; Leighton, Bird, Orsini, & Heyes, 2010). Hence, combining automatic imitation with neuroimaging provides some insights into how the social sensitivity of these behaviors is implemented neurally (e.g. Klapper, Ramsey, Wigboldus, & Cross,

2014; Rauchbauer, Majdandžić, Hummer, Windischberger, & Lamm, 2015; Wang & Hamilton, 2015). However, in contrast to mimicry, during automatic imitation tasks participants' attention is explicitly guided towards the specific target actions that they are prepared to perform. Indeed, a recent neuroimaging experiment suggests that natural behavioral mimicry and automatic imitation rely to a different degree on specific neural correlates (Hogeveen, Obhi, et al., 2015). Thus, while providing an experimental task in which social modulation of perception-behavior mapping can be readily tested, neuroimaging during automatic imitation tasks cannot fully address how naturalistic observation of an interaction partner leads to behavioral mimicry.

The Mirror System

The discovery of so called 'mirror neurons' provided the neuroanatomical correlates of the perception-behavior mapping evident from the behavioral tasks. Single-cell recordings of the macaque cortex showed that a selection of neurons in the rostral premotor cortex fired both when the individual carried out an action and when the individual observed the experimenter carrying out a similar action (di Pellegrino et al., 1992; Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996). Neurons with similar properties were further detected in the macaque inferior parietal lobule (Rizzolatti & Craighero, 2004). In 2010, single-cell recordings in the human cortex provided evidence for the presence of neurons with mirroring properties in humans (Mukamel, Ekstrom, Kaplan, Iacoboni, & Fried, 2010). Moreover, converging evidence from multiple neuroimaging techniques suggests a similar mirror system with multiple nodes is present in humans (transcranial magnetic stimulation: Fadiga, Craighero, & Olivier, 2005; electroencephalography: Fox et al., 2016; magnetic resonance imaging: Molenberghs, Cunnington, & Mattingley, 2012).¹

Recently, several studies have investigated how social interactions and their characteristics influence the degree of mirror system activation. Hogeveen and Obhi (2012) investigated the role of prior social interaction on participants' action mirroring using transcranial magnetic stimulation (TMS). After having interacted with the experimenter or not, participants observed simple action stimuli in which a hand or robot squeezed a ball. Sensorimotor facilitation was found to be higher when participants observed a human hand performing the

¹ It seems as if there are as many different terms for this overlapping representation of action perception and execution as there are researchers investigating it. Here, an attempt has been made to conform to the terminology of the experimental discipline from which the research originates; the general terms 'perception-behavior link' or 'perception-behavior mapping' are used to refer to the behavioral phenomena while deviations of 'mirror system' are used in the context of neuroimaging experiments. Yet, per neuroimaging technique, the way mirror system activation is measured differs, hence at times more specific terminology is used, such as 'sensorimotor facilitation' in the context of TMS studies as the sensorimotor cortex is the site of stimulation.

action than when a robotic arm did so, but only in the prior-interaction condition. Interestingly, in an exploratory analysis, participants who had mimicked the experimenter during the initial interaction were found to have significantly higher mirror system activation during the human action stimulus than participants who had not mimicked (Hogeveen & Obhi, 2012). Subsequently, the effect of having been mimicked was investigated in a similar paradigm using electroencephalography (EEG). Participants in this study underwent two sessions of observing the simple squeezing action with an experimental manipulation in between. Participants who engaged in an interaction in which they were mimicked in between stimulus sessions showed a significant increase in mirroring from the pre to the post stimulus observation session (Hogeveen, Chartrand, et al., 2015). These studies suggest that action mirroring is generally enhanced following natural social interactions in which mimicry is likely to occur, but do not yet specifically indicate the role of mirroring in producing mimicry.

Online mirror system activation has also been shown to be sensitive to social manipulations in the stimuli. TMS (Molnar-Szakacs, Wu, Robles, & Iacoboni, 2007) and EEG (Gutsell & Inzlicht, 2013) experiments have found differences in mirroring of racial in- and out-groups. For example, participants who observed individuals from their in-group and from different out-groups perform a simple action showed more mirror activation while watching in-group members than the out-group members. Mirroring of the out-groups was related to the stereotypes of those out-groups and participants' liking; the more negatively stereotyped and disliked the group the less mirror system activation (Gutsell & Inzlicht, 2010). Similar effects have been documented in a study using a minimal group procedure in which participants are assigned to one of two groups upon arrival. In this magnetic resonance imaging (MRI) study, participants had to judge whether an in-group member or an out-group member was faster in pressing a button. In participants who showed an in-group bias in their speed judgments, activation of the inferior parietal lobule, a mirror system region, showed a significant increase in activation when participants viewed their own group's actions versus the out-group's actions (Molenberghs, Halász, Mattingley, Vanman, & Cunnington, 2013). These studies indicate that the extent to which mirroring takes place is modulated by social dynamics. Thus, it might be the case that the social effects of mimicry are underpinned by selective mirror system activation as a function of social relevance.

Taken together, perception-behavior mapping can be measured in behavioral tasks and is neurally underpinned by a mirror system network in which the observation and execution of actions are associated. Interestingly, both behavioral and neural measures of perception-behavior mapping demonstrate modulation

by the social characteristics of (or directly preceding) the action observation. Though there is little direct evidence of online mirror activity playing a role in the generation of behavioral mimicry, it most likely serves as the basis of mimicry's neural mechanisms.

OUTLINE OF THE THESIS

The aims of the present thesis were to investigate whether young children display social behavioral mimicry and to explore the developmental and neurocognitive mechanisms contributing to this behavior. The reviewed literature serves as the theoretical basis of these investigations. The developmental trajectory of imitation suggests that mimicry likely develops during early childhood. Building on an already capable mirror system, late toddlerhood and early childhood are periods in which social imitation undergoes considerable advances. After an initial increase, the natural occurrence of explicit imitation as an affiliation tool among peers decreases from the age of 3. It has been suggested that explicit forms of affiliative imitation are gradually made redundant through the emergence of other affiliation means. It could hence be the case that as a nonverbal social behavior, mimicry begins to fulfill this affiliative function around 3 years of age. Subsequently, the increasing social sensitivity of children's behavior during experimental imitation tasks reflects a developing social understanding, which may gradually drive an increase in the production of social mimicry into early childhood. The concurrent improvements in behavioral control could help regulate the selectivity of this social behavior. Furthermore, underlying mimicry is likely the perception-behavior link, as it typically generates imitative motor activity. Like the execution of behavioral mimicry, the extent to which actions are neurally mirrored is dependent on the social relevance of the individuals being observed. This enhanced mirror activity for relevant interaction partners is likely an essential component of producing behavioral mimicry.

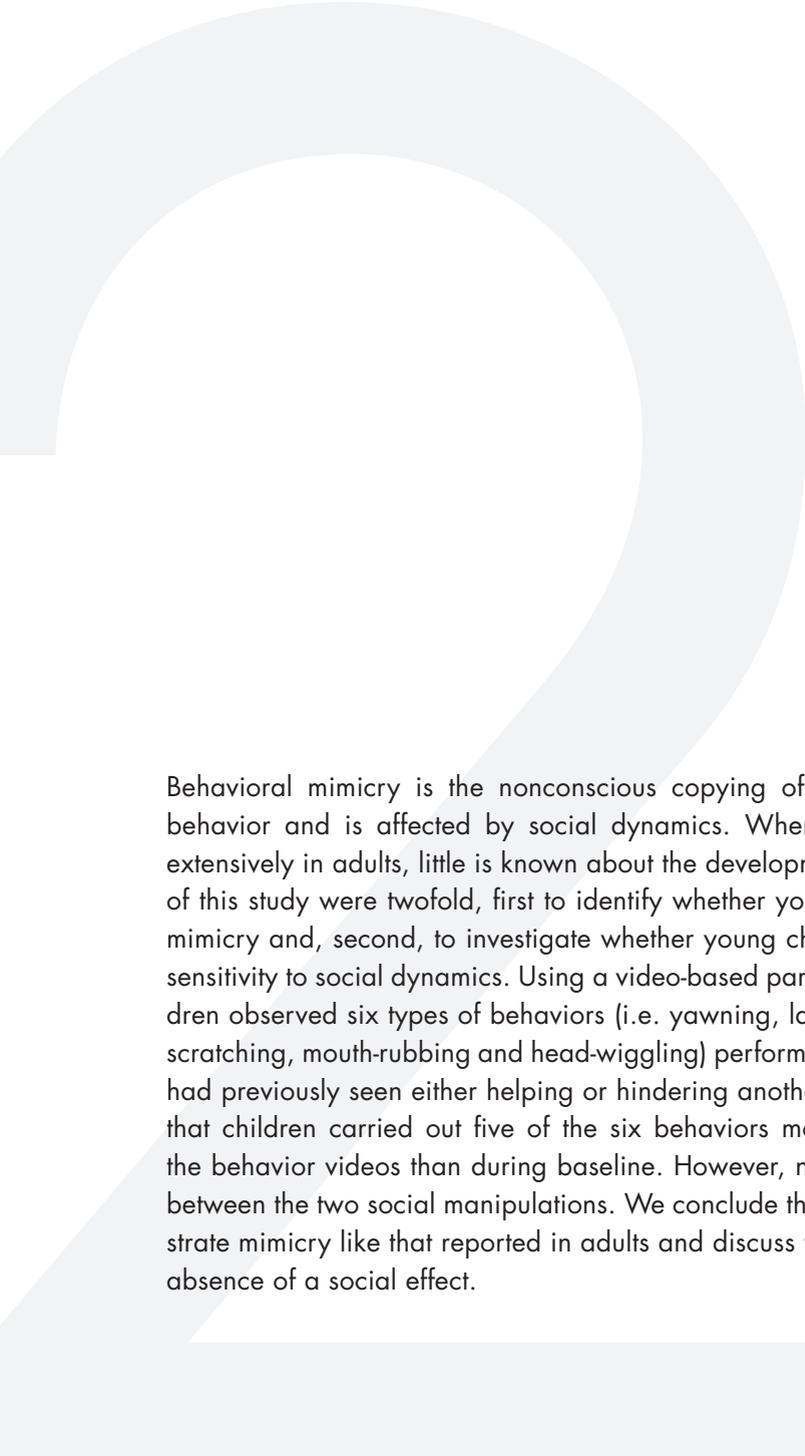
Following from this, we designed a series of experimental investigations. We began by examining whether 3-year-olds display social behavioral mimicry. In *Chapter 2*, we developed a video paradigm in which children observed meaningless mannerisms being performed by kind or unkind adult models with neither instruction nor encouragement to copy these behaviors. Subsequently, the development of social mimicry during early childhood was examined. *Chapter 3* presents an adapted version of the video paradigm in two studies, one with 3-year-olds and one with 4- to 6-year-olds. A group manipulation was

implemented to determine the influence of affiliation on children's behavioral mimicry.

Next, we studied the role of social-cognitive development in children's social behavioral mimicry. *Chapter 4* presents a novel, semi-live, behavioral mimicry paradigm used in conjunction with a social manipulation. Measures of the 5-year-old participants' inhibitory control and social understanding were related to individual differences in their (social) mimicry.

Lastly, we explored the neurocognitive basis of mimicry. The social sensitivity of perception-behavior mapping in young children was examined in *Chapter 5*. Here, the tablet adaptation of the motor interference task was used in combination with a social group manipulation. As the final empirical chapter, *Chapter 6* presents a naturalistic TMS paradigm used to test the role of online mirror system activation in mimicry. Through providing a cover task unrelated to the motor behaviors of the confederates, adult participants' sensorimotor simulation was measured as they observed confederates perform meaningless mannerisms.

The thesis is concluded in *Chapter 7* with a *General Discussion* of the reported findings and their implications for the study of copying development, behavioral mimicry, and social interaction.



Behavioral mimicry is the nonconscious copying of an interaction partner's behavior and is affected by social dynamics. Whereas it has been studied extensively in adults, little is known about the development of mimicry. The aims of this study were twofold, first to identify whether young children demonstrate mimicry and, second, to investigate whether young children's mimicry displays sensitivity to social dynamics. Using a video-based paradigm, 40-month-old children observed six types of behaviors (i.e. yawning, laughing, frowning, cheek-scratching, mouth-rubbing and head-wiggling) performed by a model which they had previously seen either helping or hindering another model. Results indicate that children carried out five of the six behaviors more often while watching the behavior videos than during baseline. However, no differences were found between the two social manipulations. We conclude that young children demonstrate mimicry like that reported in adults and discuss the possible causes of the absence of a social effect.

Chapter 2

Evidence for Nonconscious Behavior-Copying in Young Children

J. E. van Schaik
R. B. van Baaren
H. Bekkering
S. Hunnius

(2013). In M. Knauff, M. Pauen, N. Sebanz, & I. Wachsmuth (Eds.), *Proceedings of the 35th Annual Conference of the Cognitive Science Society*. (pp. 1516–1521). Austin, TX: Cognitive Science Society.

An often unnoticed component of social interactions is behavioral mimicry. Mimicry can be defined as nonconsciously adopting the behaviors of an interaction partner (van Baaren et al., 2009). In one of the first comprehensive studies of mimicry, participants were exposed to foot-shaking or face-rubbing confederates with smiles or neutral expressions on their faces. Chartrand and Bargh (1999) showed that participants were more likely to carry out the modeled behaviors and expressions than the non-modeled behaviors and expressions. Importantly, replicating these behaviors occurred outside of the participants' awareness (Chartrand & Bargh, 1999).

In contrast to the extensive adult literature on mimicry (for a review see Chartrand & van Baaren, 2009), exceptionally few studies have investigated the development of mimicry. Some authors have documented neonatal imitation (e.g. Meltzoff & Moore, 1977, 1983). Others, however, note the lack of breadth of these behaviors and have been unable to replicate original findings with older infants and young children (e.g. Anisfeld, 1996; Jones, 2007). Additionally, in such studies, infants and young children are encouraged to replicate modeled behaviors (e.g. Jones, 2007), which stands in contrast to the uninstructed mimicry reported in adults. In one study that did not give replication instructions, children saw video stimuli in which someone often yawned, but children under the age of five did not demonstrate instances of yawning (Anderson & Meno, 2003). In a live paradigm, only three out of 40 children under the age of four demonstrated contagious yawning (Helt et al., 2010). Similarly, Over and Carpenter (2009) report that, in a pilot study, 5-year-old children who interacted with an adult who repetitively touched her face failed to mimic this behavior. Notably, the authors posited that there was little evidence to suggest that children under the age of five exhibit mimicry of the sort found in adults (Over & Carpenter, 2009).

Not only do adult studies indicate the uninstructed nature of mimicry, but they also bring to light its sensitivity to social dynamics. For example, liking one's interaction partner has been shown to increase mimicry rates, both when liking was preexistent and manipulated (Likowski, Mühlberger, Seibt, Pauli, & Weyers, 2008; McIntosh, 2006). Although there is no evidence of uninstructed mimicry in young children, a form of imitation has been shown to be affected by social dynamics. Over-imitation (also called affiliative imitation) is the replication of actions shown during a task demonstration that are unrelated to achieving the desired end-state of the task (Over & Carpenter, 2012). In a conceptual replication of an adult study by Lakin, Chartrand and Arkin (2008) which showed that being socially excluded lead to higher mimicry rates, Over and Carpenter (2009) found that priming 5-year-olds with social exclusion increased over-

imitation rates (Over & Carpenter, 2009), indicating that non-mimicry forms of behavior replication are sensitive to social factors in young children.

Children's sensitivity to social dynamics is also manifest in other behavioral measures. One study showed that 3-year-olds helped helpful adults more than destructive adults (Vaish, Carpenter, & Tomasello, 2010). Kenward and Dahl (2011) demonstrated that, when given an uneven number of biscuits, 4.5-year-olds distributed more biscuits to puppets they saw helping another puppet than to puppets they saw violently hindering the other puppet. Three-year-olds did not distinguish in their biscuit-distribution but the authors suggest this was because they were shocked by the violent nature of the events and were not sure which puppet was which (Kenward & Dahl, 2011).

Thus far, no studies have reliably found uninstructed mimicry during early childhood, and it is hence also unknown if children's mimicry is affected by social dynamics. In the present study, we first aimed to identify whether young children demonstrate mimicry like that found in adults. Importantly, we incorporated a range of behaviors, such as facial expressions and manual behaviors, to investigate the generality of young children's mimicry. Also, as past adult studies have successfully used videos to elicit mimicry (e.g. Lakin & Chartrand, 2003; Platek, Critton, Myers, & Gallup, 2003), we chose to present the stimuli as videos to ensure that all children saw identical behaviors. Moreover, this provided the children with a 'task', namely to watch TV, which is in line with the contention of van Baaren and colleagues (2009) that during mimicry experiments the focus should not be on the behaviors specifically. We incorporated a baseline measure so as to compare natural behavior rates with those elicited by observation within participants, because past studies indicate that individual differences influence mimicry rates (e.g. Chartrand & Bargh, 1999; Platek et al., 2003; Sonnby-Borgström, 2002). We hypothesized that children would demonstrate the behaviors at greater frequencies while watching the behavior videos than during baseline.

The second aim was to address whether mimicry is sensitive to social dynamics at three years of age. As past studies demonstrated that children around three and four years of age show differential treatment of helpers versus hinderers (Kenward & Dahl, 2011; Vaish et al., 2010), we used a similar paradigm to manipulate the social dynamics. We designed the models' interactions such that the helper would come across as a nice individual whereas the hinderer would be seen as a mean but not violent individual. In this manner, we aimed to implement a similar effect as in the manipulated-liking designs of adult mimicry studies (Likowski et al., 2008; Mcintosh, 2006). Due to possible carry-over effects from previous interactions (e.g. Lakin & Chartrand, 2003), we used this social

manipulation as a between-participants factor, such that half of the children were randomly assigned to the helper condition and half to the hinderer condition. We hypothesized that children would mimic helpers more than hinderers, replicating the pattern of higher mimicry rates for liked individuals in adult studies.

METHODS

Participants

Participants were recruited through the database of volunteer families of the Baby Research Center Nijmegen. Signed consent was obtained from parents beforehand. Thirty-three children participated in this study (Age: $M = 39.7$, range: 39.2-40.2 months; 23 girls). Seven children were excluded due to not wanting to watch the videos ($n = 1$), technical error ($n = 1$), and not meeting the inclusion criteria of having attended to at least 40% of the behavior videos ($n = 3$) or having watched each behavior video at least once ($n = 2$). Thus, the final sample consisted of 26 children (19 girls).

Stimuli

The stimulus videos for the experiment were made using a digital video camera (Sony Handycam, DCR-SR190E) and were digitally muted. Two types of videos were recorded, social manipulation videos and behavior videos.

Figure 1.2 shows the final scene of the helper video, and gives an indication of the scene composition used in the social manipulation videos. In both the helper and hinderer videos, a stuffed animal was initially positioned in the left, front corner of the table, and the helper or hinderer (H) walked in from the left and the neutral model (N) from the right, each sitting down at their respective sides of the table. After N failed to reach the stuffed animal from her position, H reached over to get the stuffed animal and held it out to N who reached for it. At this point the videos differed; in the helper videos, H passed the stuffed animal to N who held it as in Figure 1.2, whereas in the hinderer videos, H pulled the stuffed animal back and held it to her chest.

Three adult female models were used. Two models were used for H (i.e. H1 and H2), who each played both the helper and the hinderer in order to control for possible idiosyncrasies of each model. The model for H was kept consistent within participants, such that children who saw H1 during the social manipulation video also saw the behavior videos of H1, and the same for H2. The H models wore a colored shirt to aid subsequent identification while N wore

black. Since N never reappeared in the behavior videos, only one model played her role.

Six different behavior videos were made. The first, yawning, was selected for its contagious qualities (Figure 1.3; Platek et al., 2003). Two emotional facial expressions, laughing and frowning (i.e. a sad facial expression), were used as they have successfully elicited mimicry in adult studies (Moody & McIntosh, 2011; Sonny-Borgström, 2002) and recently also in school-aged children (Deschamps et al., 2012). Two manual behaviors were loosely based on those used in interactive adult studies (e.g. Chartrand & Bargh, 1999; Lakin & Chartrand, 2003), namely using the fingertips to scratch the cheek (i.e. cheek-scratching) and rubbing the fingertips back and forth across sealed lips (i.e. mouth-rubbing; Figure 1.5). Finally, in the head-wiggling clip the model moved her head from side to side while looking forwards. Each behavior video showed the model in a neutral position for the first and last 500 ms. Pilot data indicated that children of this age were capable of replicating all behaviors.

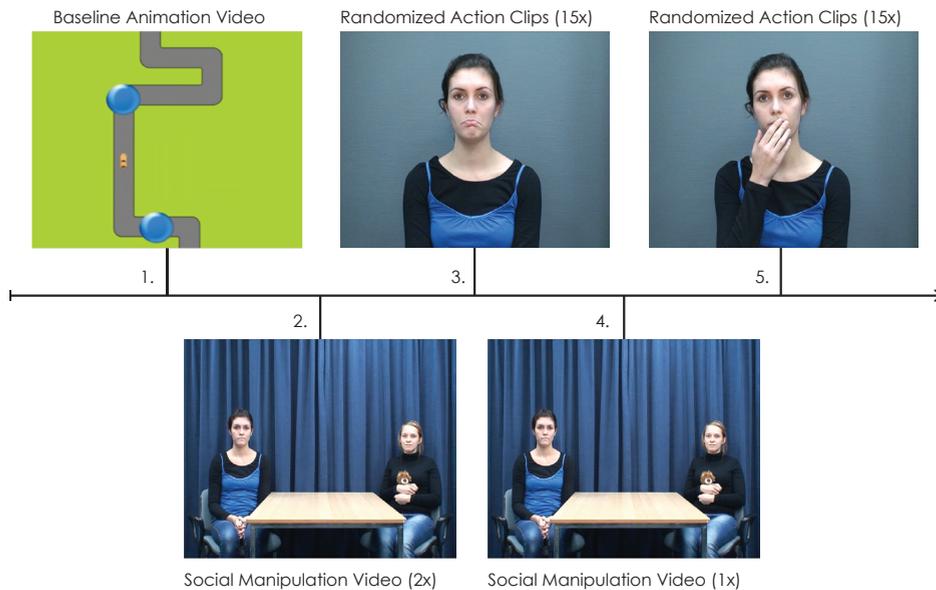


FIGURE 1 | Experimental design.

Design

This experiment consisted of three types of stimuli: the baseline, the social manipulation and the behavior videos. For the baseline, a nonsocial video (73.7 s) from an unrelated experiment was shown displaying a single racecar driving

through a racetrack (Figure 1.1; Immens, 2011). Next, the social manipulation video (average duration 23 s), depending on the condition the participant was assigned to, was shown twice (Figure 1.2). The behavior videos (average duration 7 s) were presented after the social manipulation videos (Figure 1.3 and 1.5). Each of the six behaviors was presented five times, resulting in 30 behavior videos in total, and after every five behavior videos an attention grabber video (2 s) was shown. After half of the behavior videos were played, the same social manipulation video was shown a third time (Figure 1.4) and was announced via a recording of a voice saying in Dutch, "Look! Again this video." Children's behavior during the third repetition of the social manipulation video was not included in the behavior rate calculations. Together, the baseline, the three repetitions of the social manipulation video and the 30 behavior videos lasted approximately 6 min. At the end of the experiment, the experimenter asked the children if they remembered the social manipulation video, if they could describe what had happened and whether the model was nice or mean, as well as whether the child remembered copying the model's behaviors.

Randomization and counterbalancing. The (pseudo)-randomizations were done using Mix (van Casteren & Davis, 2006). Participants were randomly assigned to one of the two conditions (i.e. helper or hinderer) and one of the two models (i.e. H1 or H2); hence there were four groups, one for every combination of condition and model. For each group there were two presentation orders of behavior videos (i.e. eight in total), which were constrained such that at least three different behavior types had to be presented before the same behavior could be shown again, and these presentation orders were counterbalanced across participants.

Procedure

Following a short play session, the child and parent were led to the experiment room. Children were seated in front of an eye-tracker (T120, Tobii Technology, Stockholm, Sweden, Tobii Studio software) either alone or on their parent's lap. A video camera (Sony Handycam, DCR-SR190E) was positioned to the side of the child such that it was not in her direct visual field but still obtained the most frontal recording angle possible. The only instructions given were to watch the videos. Upon conclusion, the participants were allowed to select a storybook or were given 10 Euros for participating in the experiment.

Coding and Reliability

The children's behavior was coded using ELAN Linguistic Annotator (Lausberg & Sloetjes, 2009). The coder was blind to condition and the order of stimulus presentation.

Although the experiment was presented on an eye-tracker so that attention could be measured precisely, the percentage of looking time according to the output was often considerably lower than the amount of time that the child actually attended the screen (for comparable eye-tracking discrepancies, see Morgante, Zolfaghari, & Johnson, 2012). For this reason, attention was coded by hand. If the child looked away for more than 5 s, turned to interact with the parent or experimenter, or was not clearly visible on the video, that duration was coded as not-attending.

Pilot data was used to create the coding scheme for the behaviors so as to accommodate how children carry out each behavior. If the child verbally labeled a behavior right before, during or after carrying it out, it was not coded as mimicry. Also, behaviors that started while the child was not attending were not coded as these might have been externally triggered. The exact coding scheme is available from the first author, with the required characteristics as follows. Yawns were coded when the lips were parted forming an O-shape. For laughing, the corners of the mouth needed to be turned upwards (i.e. smiles were also counted) while for frowns they needed to be turned downwards. A cheek scratch was coded if the child brought her hand to her cheek or forehead and made scratching movements with her fingers. If the child rubbed her fingers over her mouth or chin it was coded as a mouth rub. Lastly, the head-wiggle was coded when the child tilted her head to the left or right and then to the other side at least once.

To ensure coding-reliability, a random sample of 20 percent of the participant videos was re-coded. The mean intraclass correlation coefficient between behavior rates of the first and second coding was $r = .98$.

Behavioral Measures

The timing of all events (e.g. onset and offset times of stimuli and the participant's behaviors) were synchronized and rounded to the nearest 100 ms. The baseline and behavior videos period were separated; the baseline consisted of the duration of the racecar animation and the behavior videos period was defined as starting when the first behavior video started and ending after the last behavior video, but with the social manipulation video in between excluded. Participant's behaviors that occurred during the behavior videos period but before the first attended behavior video of that type were excluded.

Behavior rates. Per participant, it was counted how often each behavior was carried out, and rates were calculated separately for the baseline and behavior videos period. Total behavior rates were calculated by dividing the total behavior count by the duration in minutes that the screen was attended. Similarly, behavior rates were calculated per behavior type using the count of just one behavior. For these separate behavior rates, the duration attended in minutes for the behavior videos period was adjusted to start from the beginning of the first behavior video of that behavior type, resulting in the separate behavior rates being lower than the overall behavior rate. Hence, per participant, per baseline or behavior videos period, seven behavior rates (i.e. behaviors per minute attended) were calculated: the overall rate and one rate for each of the six behavior types.

Analysis

Several comparisons were run to check that the models and the presentation orders did not have an effect on behavior rates during the behavior videos period and were run separately for the two conditions. The helper condition consisted of 12 participants, 5 of whom saw the videos of model H1, while the hinderer condition had 14 participants, 7 of whom saw model H1. Independent-samples *t*-tests and Mann-Whitney U-tests compared the effect of model (e.g. H1 or H2) on total behavior rates and separate behavior rates, respectively, and Kruskal-Wallis H-tests compared the effect of the presentation orders on both total behavior rates and separate behavior rates. There were no effects of model or presentation orders for total or separate behavior rates in either condition (all *ps* > .1). Therefore, the models and presentation orders were collapsed in the subsequent analyses. Additionally, Mann-Whitney U-tests revealed no differences in behavior rates between children sitting on their parents' laps and those sitting alone on the chair during either the baseline or the behavior videos period (all *ps* > .2).

RESULTS

Out of the 26 participants, 25 participants demonstrated at least 1 of the 6 behaviors during either the baseline or the behavior videos period, and 23 participants carried out the behaviors more often while watching the behavior videos than during baseline.

Since it first needed to be investigated whether the two conditions (i.e. groups of participants) differed, the hypothesized difference between the helper and

hinderer condition during the behavior videos period was tested. However, a Mann-Whitney U-test revealed no significant difference in total behavior rates between conditions ($p > .4$). Hence, for the subsequent comparisons the participant groups were collapsed across conditions.

To investigate whether behavior rates differed between baseline and the behavior videos period, a paired-samples t -test was used to compare total behavior rates. Children carried out the behaviors significantly more often during the behavior videos period ($M = 2.38$ behaviors per min, $SE = 0.24$) than during the baseline ($M = 0.92$ behaviors per min, $SE = 0.33$; $t(25) = -4.3$, $p < .001$, $r = .65$).

Subsequently, each separate behavior was investigated using Wilcoxon signed-rank tests, and alpha was corrected for multiple comparisons using a Bonferroni correction² (Figure 2). During the behavior videos, the rates of yawning, frowning, mouth-rubbing and head-wiggling, were significantly higher than the baseline rates of yawning ($z = 3.18$, $r = .44$), frowning ($z = 2.74$, $r = .38$), mouth-rubbing ($z = 2.61$, $r = .36$) and head-wiggling ($z = 2.93$, $r = .41$; all $ps < .008$), respectively. Cheek-scratching occurred more often during the behavior videos period than during the baseline at a level of marginal significance ($p = .011$). Laughing did not differ significantly between the two periods.

For the five behaviors with significant and marginally significant effects, it was investigated post hoc whether any one behavior was more likely to be replicated than the other behaviors. A Friedman's ANOVA was used to compare the difference in behavior rates between baseline and behavior videos period (i.e. behavior videos period behavior rate minus baseline behavior rate) between the behaviors. No differences between the behaviors were found (all $ps > .7$).

A Mann-Whitney U-test showed that the children's answers to the question of whether they consciously replicated the model's behaviors were not predictive of their behavior rates during the behavior videos period ($p > .6$).

DISCUSSION

This study aimed to identify and investigate mimicry in 40-month-old children. We found that children carried out the behaviors significantly more often while watching the behavior videos than while watching the baseline video. This was evident across individuals, as 23 out of 26 participants showed higher behavior

² The Bonferroni correction was calculated by dividing the alpha level (one-tailed) by the number of comparisons (i.e. six). Hence, adjusted alpha levels were 0.008 for significance values of $p < .05$ and 0.017 for marginal significance values of $p < .1$.

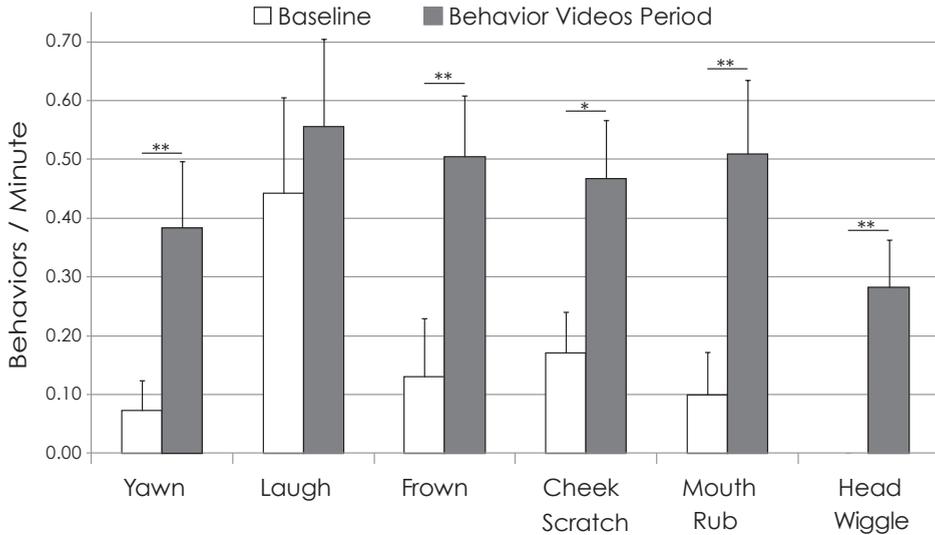


FIGURE 2 | Mean behavior rates of each behavior type for the baseline and behavior videos period. Error bars indicate one standard error above the mean; ** $p < .008$, * $p = .011$.

rates during the behavior videos period than during baseline, and across behavior types, as five of the six behaviors were mimicked. Yawning, frowning, mouth-rubbing, and head-wiggling all occurred at significantly greater rates during the behavior videos than during baseline and cheek-scratching showed this effect at a level of marginal significance. Of the mimicked behaviors, no one behavior was more likely to be mimicked than others, while controlling for baseline rates.

Mimicry of these behavior types have, to the best of our knowledge, not been tested during early childhood before, with the exception of yawning. Helt and colleagues (2010) report very low rates of yawning in live paradigms under the age of four and Anderson and Meno (2003) did not find any instances of yawning during video watching in three-year-olds. In their video-based study, children were instructed to clap whenever they saw a yawn; as also suggested by Helt and colleagues (2010), the disparity between their findings and ours may be a result of the assigned tasks, since our simple instructions to watch the videos better resemble the uninstructed nature of adult mimicry studies. Indeed, the behavior rates during the behavior videos period of our study are similar to the behavior rates measured during live interactions in adults. For example, Chartrand and Bargh (1999) found an average rate of .57 face-rubs per minute, which closely corresponds to the children's average behavior rate of .51 for mouth-rubs.

The only behavior that did not demonstrate a mimicry effect in the current study was laughing. This was likely caused by the children's enjoyment of the baseline video, as average laughing rates during the baseline far exceeded those of the other behaviors' baseline rates. Although the baseline video was selected for its neutrality and nonsocial nature, the animation still needed to be, and in fact was, attractive enough for children to attend to it.

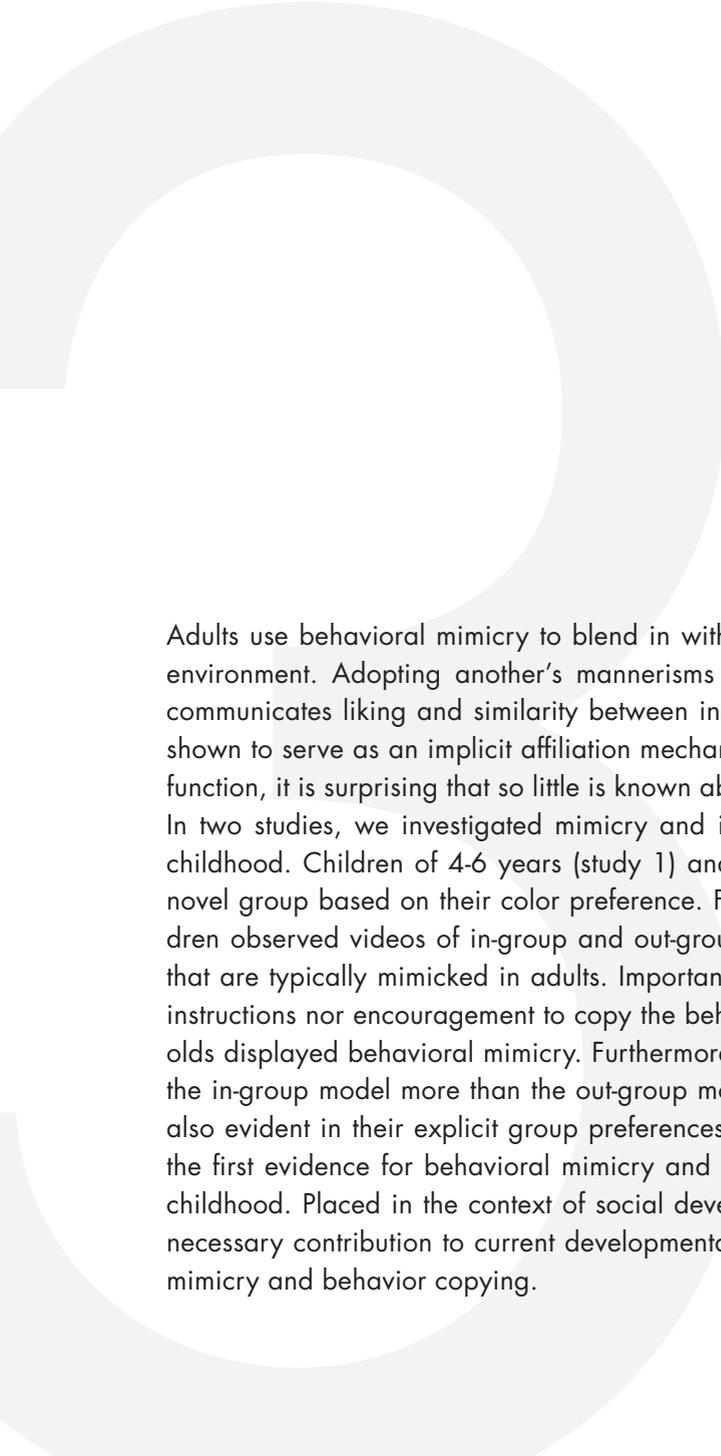
An important characteristic of mimicry is that it occurs outside of the awareness of both the individual mimicking and the individual being mimicked (Chartrand & van Baaren, 2009). Children were asked at the end of the experiment whether they copied the model while watching the behavior videos, and their answers were not related to their actual mimicry rates. Additionally, during a pilot study children were instructed to copy the behaviors, but it became apparent that they found it unusual to consciously replicate the behaviors of a non-responsive model, even when encouraged by their parents. Furthermore, our coding scheme ensured that the few cases in which children verbally labeled a carried-out behavior, indicating that they were focusing on doing that behavior, were not counted as mimicked behaviors. Anecdotally, several parents remarked that they were surprised to see their child replicate the behaviors seemingly automatically. Altogether, there is sufficient evidence to indicate that the children nonconsciously replicated the behaviors, in line with the definition of behavioral mimicry.

This study further investigated whether children's mimicry is sensitive to social dynamics. To influence the social dynamics, a helper-hinderer manipulation was used in a between-participants design. However, no significant differences between the conditions were found. Given that past studies have linked mimicry with social perspective taking skills (e.g. Chartrand & Bargh, 1999; Platek et al., 2003), it might be that the sensitivity of mimicry to social factors gradually develops during childhood as an effect of increasing social cognition and experience. However, it should be considered whether the social manipulation could have been ineffective. A limitation of the present study was that the social manipulation and behaviors were recorded as separate video clips with different background settings. Since Kenward and Dahl (2011) reported that their participants had difficulty later identifying the puppets, we allocated the helper and hinderer models a colored shirt to aid later identification. Nonetheless, the different setting of the two video types may have prevented children from making the link between the model in the social manipulation video and the model in the behavior videos. More support for this notion comes from recent pilot data with 5½-year-olds, which indicated that children older than those in this study often failed to relate the model in the behavior videos to the model in the social

manipulation video seen before. A similar limitation was that video presentation prevented participants from actually affiliating with the model, thereby possibly preventing an affiliation-driven social effect, as suggested by Over and Carpenter (2012) regarding an over-imitation study by Nielsen, Simcock and Jenkins (2008).

The findings of this study highlight avenues for further research into the neural and cognitive underpinnings of mimicry. Whereas a perception-behavior matching system founded in imitation research has been suggested to also underlie mimicry (Chartrand & van Baaren, 2009), it is unclear whether neural differences exist between nonconscious mimicry and instances of conscious motor observation and replication. Additionally, cognitive mechanisms have been suggested to contribute to imitative behaviors (e.g. Meltzoff, 2007; Woodward, Sommerville, Gerson, Henderson, & Buresh, 2009), and future studies should investigate whether similar mechanisms, and the development thereof, are involved in mimicry's reported social sensitivity.

In conclusion, this study is the first to identify uninstructed behavioral mimicry in 40-month-old children. The spectrum of behaviors for which this was the case reflects the repertoire of mimicked behaviors in the adult literature (Chartrand & van Baaren, 2009), and provides a basis for future research investigating the underlying neural and cognitive processes. It is unclear whether the lack of social modulation of mimicry was a result of experimental design or an effect of social-cognitive development, and this posits further investigation.



Adults use behavioral mimicry to blend in with (or stand out from) their social environment. Adopting another's mannerisms and behaviors, or 'mimicking', communicates liking and similarity between interaction partners and has been shown to serve as an implicit affiliation mechanism. Given this important social function, it is surprising that so little is known about the development of mimicry. In two studies, we investigated mimicry and its social sensitivity during early childhood. Children of 4-6 years (study 1) and 3 years (study 2) first chose a novel group based on their color preference. Following a baseline phase, children observed videos of in-group and out-group models performing behaviors that are typically mimicked in adults. Importantly, the children received neither instructions nor encouragement to copy the behaviors. Both 3- and 4- to 6-year-olds displayed behavioral mimicry. Furthermore, the 4- to 6-year-olds mimicked the in-group model more than the out-group model, and this in-group bias was also evident in their explicit group preferences. Together, these studies present the first evidence for behavioral mimicry and its social sensitivity during early childhood. Placed in the context of social development, the findings provide a necessary contribution to current developmental and psychological theories on mimicry and behavior copying.

Chapter 3

Little Chameleons: The Development of Social Mimicry During Early Childhood

J. E. van Schaik
S. Hunnius

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Just as chameleons change color to match their environment, humans adapt their behaviors to the specifics of an interaction (Chartrand & Bargh, 1999). One way this chameleon effect manifests itself is through behavioral mimicry, the copying of one another's postures, mannerisms, or behaviors. The extent to which mimicry occurs is a function of the social factors governing the interaction. Adults mimic individuals they like and, in turn, being mimicked leads to liking (Chartrand & Lakin, 2013; Lakin & Chartrand, 2013).

Correspondingly, mimicry can be used to pursue affiliation goals (Lakin & Chartrand, 2013), such as those deriving from an individual's need to belong (Baumeister & Leary, 1995). In the context of social groups, people hold stronger affiliation goals for certain individuals, such as in-group members, than for others (Tajfel, 1974). Indeed, mimicry might be interpreted as communicating 'I (am) like you' (Lakin et al., 2008), as exemplified in adult participants' mimicry of in-group but not out-group members (Yabar et al., 2006). An ostracism manipulation further demonstrates mimicry's affiliative message; being excluded by in-group members selectively increased participants' mimicry of in-group members (Lakin et al., 2008). Consequently, mimicry has been described as the social glue that bonds individuals, and hence groups, together (Lakin et al., 2003).

The importance of mimicry is also evident in its everyday presence, as shown in both observational studies as well as laboratory experiments (for a review see Chartrand & Lakin, 2013). The automaticity of mimicry was demonstrated in a study in which participants mimicked the mannerisms of an individual they would later interact with even though they were observing her on what was known to be a one-way TV (Lakin & Chartrand, 2003). Likewise, in a virtual reality study, participants rated mimicking avatars as more realistic and social than non-mimicking avatars while unaware of the mimicry (Bailenson & Yee, 2005), indicating mimicry's commonplace presence in human behavior. Accordingly, deficits in mimicry have been found in several social disorders, including developmental disorders such as autism (Duffy & Chartrand, 2015; Hamilton, 2013). Taken together, one might expect social behavioral mimicry to be an essential factor in social development and, at least, an implicit indication of a child's sensitivity to their social environment. Surprisingly, though, almost nothing is known about the development of mimicry in ontogeny.

Only a handful of studies have investigated behavioral mimicry during early childhood. The few studies that investigate social yawning suggest that children start mimicking yawns around the age of 4 or 5 years (Anderson & Meno, 2003; Helt et al., 2010; Millen & Anderson, 2011). Importantly, though, studies often explicitly direct children's attention towards the yawns. This stands in

contrast to adult studies in which the to-be-mimicked behaviors are not explicitly emphasized. Only one study has investigated children's mimicry in this way for a range of behaviors that are typically mimicked in adults (van Schaik, van Baaren, Bekkering, & Hunnius, 2013). In this study, three-year-olds were first shown a video in which a model helped another person get a toy or prevented the person from getting the toy. Subsequently, they observed videos in which the helper or hinderer performed typically-mimicked behaviors. Results indicated that the children mimicked the models and did so equally across behavior types, including yawning and face-rubbing. However, their mimicry was not affected by whether the model had helped or hindered (van Schaik et al., 2013). Thus, there is only limited evidence to suggest that young children mimic others' behaviors, and it is unknown whether their mimicry can be sensitive to social factors as is the case in adults.

To some extent, research on imitation can shed light on how social mimicry might develop. Yet, it is important to recognize that imitation differs from mimicry. While imitation is often intentional and object- or effect-directed, mimicry involves behaviors that carry little meaning in themselves, such as bouncing one's foot, and generally occurs outside of the awareness of both the mimicker and the mimicked (Chartrand & van Baaren, 2009). As a result, the translation of findings from thorough and informative investigations of imitation development (e.g. Jones, 2007) to mimicry research is limited, since often the behaviors involve exciting effects and infants are encouraged to produce the actions. Recent evidence, though, shows that young children's imitation, like mimicry in adults, is affected by wanting to communicate liking and similarity to the model and that imitation gains this social sensitivity during early childhood (Over & Carpenter, 2012). During this period, children increasingly make use of similarities to guide liking. Three-year-old children prefer to play with others who share their preferences and physical features, such as hair color (Fawcett & Markson, 2010b), and expect that shared features between themselves and others also indicate that other preferences are shared (Shutts, Roben, & Spelke, 2013). By extension, young children categorize similar individuals into groups and prefer members of their own group (i.e. in-group bias; Dunham, Baron, & Banaji, 2008). In-group bias has also been found for novel-group divisions that carry no prior meanings nor exposure from the age of 3 years onwards, although the strongest evidence for this exists from the age of 5 (Dunham et al., 2011; Patterson & Bigler, 2006).

The reviewed findings suggest that social development during early childhood entails an increasing awareness of (the dynamicity of) social relationships, such as those based on shared preferences, and an extension of belonging that motivates affiliation with similar others. Considering this gradual emergence of

such facets of social cognition, we expect that socially-selective mimicry arises during these early childhood years, building on an already capable behavior copying system. Here, we investigated the developmental trajectory of social mimicry by using a video-based paradigm in which female models displayed behaviors that are typically mimicked in adults. We used a novel-group allocation based on preferences to affect the extent to which children would want to affiliate with the models. In the first study, we tested the hypothesis that 4- to 6-year-olds' mimicry is sensitive to novel-group membership.

STUDY 1

Method

Participants. Forty-three children aged 49 to 80 months from mixed-year classrooms participated at a Dutch primary school that was approached to partake in this study. Three children were excluded from the analyses: 1 child did not want to complete the experiment and 2 children did not visually attend to at least 50% of the videos. The final sample consisted of 40 4- to 6-year-olds (17 girls; Age: $M = 65.10$, $SD = 7.99$, $Mdn = 64.2$ months). The two classrooms were thanked for participating with a board game and a storybook. This line of research was approved by the social science faculty's ethics board.

Behavior videos. Four behaviors were selected for the current experiment from a previous developmental mimicry study and the same videos were used (van Schaik et al., 2013). The behaviors consisted of two non-manual behaviors (yawning and nodding side-to-side) and two manual behaviors (rubbing the lips and scratching the cheek). These behaviors were carried out by two different female models, one wearing a blue shirt and the other a yellow shirt (N.B. in the previous study, the models were mimicked equally often and there were no differences in how often children mimicked the different types of behaviors; van Schaik et al., 2013). Each model performed one non-manual behavior and one manual behavior while the other model performed the other behavior of each type, counterbalanced across participants. The videos showed the upper bodies of the models facing the camera and the models, though they did not speak to the viewer, made eye-contact on and off in order to be social but not appear threatening. Each video lasted roughly 7 s and started and ended with 500 ms of the model in a neutral position.

Procedure. Two experimenters ran the study; the primary experimenter retrieved each child one-by-one from the classroom and ran the experiment,

while the other set up the experiment between consecutive participants and unobtrusively operated the test-computer.

The experiment started with the novel-group allocation. The experimenter uncovered two pieces of paper laying side by side, one blue and one yellow, and asked which color the child liked best. Once the child had selected a color, the experimenter told her that she now belonged to that group (17 children (43%) chose yellow). She took away the non-selected color, informing the child that their color would stay in front of them so that they could always see which group they belonged to. The child was also presented with a vest in their chosen color. The experimenter helped the child put on the vest and then pointed the child to a mirror, emphasizing the color of the vest while the child was looking at herself. The experimenter then seated the child in front of the computer screen and informed the child that the computer would provide the rest of the instructions. The experimenter subsequently pretended to work on a laptop at the other end of the table.

The computerized part of the experiment was instructed by a pre-recorded female voice and was run using Presentation software (www.neurobs.com). It consisted of six phases (see Figure 1). First, group membership was emphasized as the voice congratulated the child on belonging to the color-group they had chosen (Figure 1.1). This was followed by the baseline phase. The voice told the child that she would first play a game to earn points for her group. The voice explained that pieces of fruit would consecutively appear on the screen and it was the child's job to say "strawberry" every time she saw a strawberry appear (Figure 1.2). The game started after the primary experimenter confirmed that the child understood the instructions. This game, which lasted 2 min, served as the baseline, as the target behaviors would later be coded during this phase to establish the natural occurrence of these behaviors. The baseline was designed like this so as to have the child sitting and paying attention to the screen in the same way as the rest of the experiment. After the game, the voice commended the child and said she had earned a lot of points for her group.

The voice then introduced the two models using neutral photos in a randomized order (Figure 1.3). The models served as the in-group model and the out-group model, depending on the child's color choice. The picture of the child's in-group model was announced by saying, "Look! She belongs to the [in-group color] group, just like you. She is also wearing [in-group color] clothes." The out-group model introduction was similarly formulated, "Look! She belongs to the [out-group color] group. She is wearing [out-group color] clothes."

The next phase of the experiment concerned the presentation of the videos (Figure 1.4). Following the model introductions, the child was told that she would

see videos of these two models. The only instruction she received was to watch the videos. The order of the videos was pseudo-randomized such that the same video could not be directly repeated and the same model was not shown more than three times in a row. Each video (i.e. behavior) was shown six times, resulting in a series of 24 videos in total.

Subsequently, to see whether the novel-group manipulation affected explicit preferences, the voice asked three questions. The voice told the child that pictures of the models would be shown (Figure 1.5) and that she would ask the child questions to which the child should respond by pointing to one of the two models. The child was asked: “Who do you like more?” (question 1), “Who would you like to play with?” (question 2), and “Who would you like to have as your teacher?” (question 3) in a randomized order. Finally, the voice thanked the child for her participation and emphasized that, because the game was over, it no longer mattered which group the child belonged to (Figure 1.6).

As in adult mimicry studies, at the end the experimenter checked whether the child was aware of her behavior during the experiment. In a funneled question sequence (Chartrand & Bargh, 1999), children were first asked whether they remembered watching the videos and if they remembered what they had done while watching. The final and crucial question asked if they had copied the behaviors that the models performed.³ In total, the experiment lasted approximately 10 min.



FIGURE 1 | Timeline of computerized experiment phases; group membership congratulations (1); baseline game (2); model introductions (3); videos of models (4); explicit preference measures (5); group neutralization (6).

³ In study 1, no children reported that they had copied the behaviors.

Coding and reliability. During the experiment the child was videotaped. Children’s behavior was blindly coded for the four target behaviors and their visual attention towards the computer screen using the coding scheme of van Schaik and colleagues (2013). Coding was carried out using ELAN Linguistic Annotator (Lausberg & Sloetjes, 2009). A second observer independently re-coded 20% ($n = 8$) of the videos and Pearson’s correlation coefficients ranged between $r = 0.82 - 1.00$ for the behaviors.

Measures. The adult mimicry literature has been inconsistent in how mimicry is quantified. Following Hogeveen and Obhi (2012), who reason that the percentage of time spent performing a behavior best represents the overall presence of the behavior during an interaction, we used behavior percentages in this study.⁴ These were calculated per phase of the experiment (i.e. baseline and videos) and per condition (i.e. in-group and out-group). This was first calculated for each behavior separately, by dividing the amount of time the child performed the specific behavior by the duration of time that the child could demonstrate the behavior. With respect to the baseline phase, this duration consisted of the entire baseline game. For the videos phase, this duration ran from the first time the video of that behavior was shown (and visually attended by the participant) to the end of the last video. Then, percentages of each behavior were added to get the total percentage of time the child performed the behaviors per phase and condition.

Results

Means and ranges of the behavior percentages are shown in Table 1, keeping in mind that this dependent variable was non-normally distributed and thus non-parametric tests were used. In order to first establish whether the children mimicked the models, total behavior percentages were compared between the baseline phase and videos phase using Wilcoxon signed-rank tests. Behavior percentages were significantly higher during the videos phase than during the baseline ($z = 2.68, p = .004, r = 0.42$). This indicates that children displayed mimicry during this experiment, and that this mimicry effect was of a medium size. This includes all participants, but it should be noted that only 18 out of the 40 participants (45%) performed any of the target behaviors during either the baseline or the videos phase.

The group manipulation was investigated next. Wilcoxon signed-rank tests indicated a medium group effect, as in-group percentages were significantly higher than out-group percentages during the videos phase ($z = 2.17, p = .015,$

4 In both studies, behavior rates (number of behaviors divided by allotted time), also commonly used in adult mimicry studies, showed an equivalent pattern of results.

$r = 0.34$), but this was not the case during the baseline ($p > .250$). Indeed, a marginally significant interaction was found, as the difference between in-group and out-group percentages during the videos phase was bigger than this difference during the baseline (Wilcoxon signed-rank; $z = 1.46$, $p = .072$, $r = 0.16$).

Furthermore, binomial tests indicate that a higher proportion of children than would be expected by chance (0.5) selected their in-group model in answer to question 1 (proportion = 0.65, $p = .04$) and question 2 (proportion = 0.73, $p = .003$). Question 3 did not show a bias (proportion = 0.5).

Finally, control analyses found that there were no differences in the percentage of time children visually attended in-group versus out-group videos (paired samples t test, $p > .250$) and that counterbalancing the behaviors across in-group and out-group models was successful (chi-square, $p > .250$). There were also no differences in behavior percentages between the behavior types (i.e. yawning, nodding, rubbing, and scratching) within the baseline and videos phases ($ps > .250$; Bonferroni corrected).

TABLE 1 | Mean and range of behavior percentages per experimental phase and per group for study 1 and study 2

		Mean	Range
Study 1	<u>Baseline Phase</u>	0.50	0 - 8.09
	<u>Videos Phase</u>	1.14	0 - 9.75
	In-group	0.82	0 - 7.85
	Out-group	0.33	0 - 2.37
Study 2	<u>Baseline Phase</u>	1.56	0 - 16.29
	<u>Videos Phase</u>	4.42	0 - 22.27
	In-group	2.81	0 - 17.06
	Out-group	1.61	0 - 9.00

Discussion

As predicted, children displayed behavioral mimicry and did so selectively. Children mimicked in-group models significantly more than out-group models, and a marginally significant interaction effect between experimental phase and social group is indicative of the mimicry effect holding primarily for the in-group. Importantly, children's looking times did not differ between in-group and out-group videos, hence they did not observe one model's behaviors more than the other's. Furthermore, the explicit preference questions corroborate the efficacy

of the social group manipulation, as on two out of the three questions children responded with an in-group preference. The absence of a preference on the third question likely reflects variability between children in whether teachers are seen as in-group or out-group members.

The pattern of results reflects those of past adult studies. Both Yabar and colleagues (2006) and Lakin and colleagues (2008) found in-group effects based on pre-existing groups. Thus, not only does this study provide what might be the first record of experimentally manipulated social mimicry in children, it also suggests that mimicry is sensitive to similar social dynamics during childhood as during adulthood. However, in a past study with younger participants, 3-year-olds' mimicry was not sensitive to a helper-hinderer manipulation. The authors suggested that this could be an effect of the video-based implementation and cognitively-demanding nature of the manipulation instead of a lack of selective mimicry at this age (van Schaik et al., 2013). Hence, it remains uncertain whether mimicry is sensitive to social factors earlier during development.

STUDY 2

In the second study, we sought to investigate whether 3-year-olds' mimicry is already sensitive to this preference-based group manipulation. Previous studies have indicated that young children's preference for similar others drive affiliative interactions during early childhood and, as a result, children might be particularly inclined to copy those who belong to their group (Haun & Over, 2015). Thus, the preference-based group manipulation of study 1, in which children receive visual reminders of their preferences, might be a more developmentally-relevant manipulation of the social dynamics than the cognitive helper-hinderer manipulation of a previous developmental mimicry study (van Schaik et al., 2013). Yet, on the basis of the limited existent evidence for mimicry at this age (e.g. van Schaik et al., 2013), it could be hypothesized that mimicry, although present at three years of age, only develops social sensitivity later during childhood.

Method

Participants. Twenty-five 3-year-olds were recruited from a database of volunteer families. Signed consent was received from all guardians. Five children were excluded from the analyses: 2 did not attend to at least 50% of the baseline or videos, 2 explicitly labeled and demonstrated the target behaviors during the videos phase, and 1 reported explicitly copying the behaviors and indeed did so. The final sample consisted of 20 3-year-olds (11 girls; Age: $M = 40.00$, SD

= 0.26, *Mdn* = 40, range = 39.5-40.4 months). During the group allocation, 10 children (50%) chose yellow. Participants could choose between a book or 10 Euros as compensation for their participation.

Procedure. The procedure and design were identical to study 1 except for a few practicalities. This study was run by only one experimenter and started with a warm-up period of coloring or playing with blocks to acclimatize the children to the lab. After the child was seated at the computer screen, the experimenter went to the other side of a room divider to operate the test computer. Also, the guardian was present, but was seated behind the child throughout the experiment. Finally, the third explicit preference question regarding group preferences for teachers was not asked because these children did not yet attend school.

Coding and reliability. Video coding and measure calculations were identical to study 1. A second observer independently recoded 20% ($n = 4$) of the videos, and Pearson's correlation coefficients ranged between $r = .85$ and $r = 1.00$ for the behaviors.

Results

A Wilcoxon signed-rank test showed a mimicry effect, as behavior percentages were significantly higher during the videos phase than during the baseline ($z = 1.66$, $p = .048$, $r = 0.26$; see Table 1 for descriptive statistics).

A comparison of in-group versus out-group percentages showed no significant differences (Wilcoxon signed-rank, $p > .250$), indicating that 3-year-olds in this study did not show a sensitivity to novel-groups in their mimicry behavior. Descriptively, while 6 children mimicked in-group over out-group models, 8 mimicked out-group models more than in-group. This flat distribution illustrates that there was also no general trend towards in-group mimicry and that the non-significant effect is likely representative. Furthermore, the participants did not show a bias in their answers to the two explicit preference questions (both questions' in-group response proportions = 0.45).

As a control, a chi-square test confirmed that counterbalancing of behavior types across in- and out-groups was successful ($p > .250$). Behavior types did not differ from one another in occurrence within the baseline nor within the videos phase ($ps > .10$; Bonferroni corrected).

Fourteen out of the 20 participants (70%) displayed at least one of the target behaviors during the experiment (i.e. baseline and/or videos phase). As an explorative measure of the effect of the experimental design on both age groups' behavior, this proportion was compared between the two age groups. A chi-square test showed a significant difference in proportions between the

3-year-olds (study 2; 70%) and the 4- to 6-year-olds (study 1; 45%; $\chi^2(1, N = 60) = 3.35, p = .034$).

Discussion

In study 2, 3-year-olds mimicked the models, but their mimicry was not affected by the social manipulation. This pattern of results reflects that of a previous study with the same age, which also found that the children mimicked but did not do so selectively in the context of a helper-hinderer manipulation (van Schaik et al., 2013). Together, these findings suggest that experimentally manipulated social dynamics are not yet affecting mimicry at this age.

Notably, though, the efficacy of the manipulation should be considered. In agreement with their mimicry, this sample's explicit preferences were also not sensitive to a novel-group manipulation. In a previous study, 3-year-olds, though only as part of an older sample, showed an in-group bias for novel groups. However, in that study the groups were instated for several weeks (Patterson & Bigler, 2006). This provided the children with extensive experience belonging to their group, which stands in contrast to the 10-minute duration of the present experiment. Still, the children in the present study could have used the models' colors as indicators of the models' preferences, since the children had gotten to choose their own color. Anecdotally, several 3-year-olds indeed explicitly emphasized the similarities; for example, during the in-group model introduction one child exclaimed, "I am also wearing yellow clothes!" However, preference studies indicate that in the years leading up to effective *minimal* group manipulations (e.g. at 5 years of age; Dunham et al., 2011; Plötner, Over, Carpenter, & Tomasello, 2015), preference-based liking is still sensitive to relevancy (Fawcett & Markson, 2010b; Mahajan & Wynn, 2012). At three years of age, children did not prefer similar others if the similarity was based on a more arbitrary dimension, such as sticker color, whereas children did prefer to play with those who shared a toy preference (Fawcett & Markson, 2010b). Thus, the color-based preferences in the current study, although more concrete than pure assignment as in minimal group paradigms, might not have been a relevant marker for 3-year-olds.

GENERAL DISCUSSION

In these two studies, we investigated how behavioral mimicry develops during early childhood. Three- and 4- to 6-year-olds displayed mimicry, as they performed the behaviors for a significantly greater percentage of time while

watching the videos than during a baseline, yet only 4- to 6-year-olds' mimicry was sensitive to a preference-based novel-group manipulation.

These studies provide developmental evidence for behavioral mimicry analogous to that recorded in adults. Mimicry in the adult literature is distinguished from imitation in that it occurs outside of awareness (Chartrand & van Baaren, 2009). The present paradigm ensured that children were neither instructed nor encouraged to copy the models' behaviors. Furthermore, those children who later reported that they had copied the behaviors and those who labeled or clearly demonstrated the behaviors to their parents during the experiment were excluded from the analyses. The adult behavioral mimicry also occurs for many different behaviors (Chartrand & Lakin, 2013) and this too is reflected in the mimicry across behavior types in this developmental sample. Hence, the present research measures a type of copying behavior that is distinct from the previous forms recorded in the developmental literature (see also van Schaik et al., 2013).

Importantly, the findings demonstrate that mimicry can be sensitive to social factors during early childhood. The older age group examined in study 1 was sensitive to the group manipulation and, correspondingly, selectively mimicked the in-group. The younger age group in study 2 did not show a group-based liking effect nor did they mimic selectively, though they did mimic in general. Thus, the development of social mimicry seems to be closely intertwined with the development of social cognition. Although the 3-year-olds were not explicitly sensitive to the group manipulation, it was also not the case that their explicit preferences were sensitive to it but that it was not reflected in their mimicry or vice versa. Tentatively, this consistency between explicit liking and mimicry in both age groups can inform theories of mimicry development.

The pattern of results highlights two factors of social-cognitive development that might influence behavioral mimicry development. First, the increased social sensitivity found between study 1 and 2 might be a function of a broadening social awareness and desire to belong. Around the ages of four and five, children are increasingly able to abstract interpersonal similarities, imitation and relationships to categorize not only their own but third-party affiliations (Over & Carpenter, 2015; Shutts et al., 2013). Thus, in a broad sense, as children become increasingly sensitive and aware of subtle social markers, this will be reflected in their behavioral mimicry. With respect to the current study, the relatively minimal though preference-based group manipulation may only have been effective in influencing the older age group's mimicry as only this group was developmentally sensitive to the manipulation to begin with.

This social component might be supplemented by a second factor of social-cognitive development, namely the increasing behavioral control during early

childhood (Carlson, 2005). Behavioral control plays a role in regulating copying in adults (Brass, Ruby, & Spengler, 2009; Hamilton, 2015; Heyes, 2013) and interpersonal coordination during early childhood (Meyer et al., 2015). Hence, behavioral control is thought to help regulate who does (e.g. in-group members) and does not (e.g. out-group members) get mimicked (Heyes, 2013). Although behavioral control was not explicitly assessed in this experiment, a quantification of whether children performed any behaviors throughout the experiment (i.e. baseline and/or videos phases) provides a general measure of the extent to which children were regulating their overt behaviors during the experiment. A significantly lower proportion of 4-6-year-olds performed any behavior during the experiment than the proportion of 3-year-olds, suggesting that the older children were regulating their behavior (i.e. inhibiting overt behaviors) more than the younger children. Since the older children, but not the younger children, mimicked selectively, it could be the case that this increased behavioral regulation in the older children contributed to the selectivity of their mimicry. However, future research will need to test this regulatory function directly.

Even though the design of this study was successful in eliciting and modulating mimicry, the results might have been limited by the arguably artificial nature of the setup. A video-based experiment was chosen because it provided a controlled means of exposing children to two models and helped maximize attention (e.g. as opposed to a live interaction where objects divert children's attention away from their interaction partner). Looking times were indeed satisfactory, as only 4 children across studies needed to be excluded for that reason. However, it might be the case that the aforementioned age group difference in the proportion of children who displayed any of the behaviors throughout the experiment and the low occurrences of mimicry in general (though cf. Yabar et al., 2006), can be attributed to the experimental design. Particularly for the older age group, the computer setting at school likely led children to think they were supposed to sit still, even though this was not instructed, eliciting extra behavior regulation. Furthermore, an individual (i.e. the model in the present studies) would need to be able to perceive that she is being mimicked in order for it to have a communicative function. There are indications that 2-year-olds are already sensitive to this nuance, as they imitate responsive models (through CCTV) more than unresponsive models (in prerecorded videos; Nielsen et al., 2008). Hence, perhaps the general mimicry effects would be stronger in the 4- to 6-year-olds and the social dynamics more salient to the 3-year-olds in a well-designed, attention-grabbing live interaction setup. Taken together, future work should address these points, building on the basis provided by these two studies.

In conclusion, during early childhood children start to act like little chameleons by using mimicry to blend in (or stand out from) their social environment. As the first study to show social mimicry in young children, this research provides previously missing contributions to theories on social mimicry (Bavelas, Black, Lemery, & Mullett, 1986; Lakin et al., 2003; Wang & Hamilton, 2012) and the development of social behavior copying (Over & Carpenter, 2012, 2013).



This study investigated the roles of social-cognitive factors on 5-year-olds' behavioral mimicry. Two groups of children were tested; the experimental group (n=28) observed a kind and an unkind adult perform face and hand rubbing behaviors while telling stories, whereas the control group (n=23) did not. Children's inhibitory control was assessed using the day-night task and their social understanding was measured through a parental questionnaire. While the experimental group performed the behaviors significantly less than the control group (i.e. a negative mimicry effect), inhibitory control predicted children's selective mimicry of the kind versus unkind adult. Additionally, overall mimicry was positively correlated with social understanding. These results indicate separate roles of inhibitory control and social understanding in the development of social mimicry.

Chapter 4

Modulating Mimicry: The Roles of Inhibitory Control and Social Understanding in 5-Year-Olds' Behavioral Mimicry

J. E. van Schaik
S. Hunnius

(submitted).

The characteristics of social interactions are continuously developing during early childhood. As children's cognitive skills improve and social experiences expand, children become increasingly able to regulate, plan, and coordinate with interaction partners (Endedijk, Cillessen, Cox, Bekkering, & Hunnius, 2015; Meyer et al., 2015; Meyer, van der Wel, & Hunnius, 2016). Importantly, such interaction behaviors foster beneficial social consequences, such as peer acceptance, liking, and sharing (Hamann, Warneken, Greenberg, & Tomasello, 2011; Ladd, 1999; Plötner et al., 2015). However, whereas task-related interaction behaviors have been the primary subject of study, the early development of implicit social behaviors that likely also constitute a part of this interaction repertoire remains uncertain. Behavioral mimicry is an implicit behavior thought to develop during early childhood, but how social and cognitive development contribute to the emergence of mimicry, and hence mimicry's role in early social interactions, is unknown.

Behavioral mimicry occurs when interaction partners copy each other's meaningless behaviors (e.g. rubbing one's face or bouncing one's foot up and down) without being explicitly aware of doing so (Chartrand & Bargh, 1999). Adult studies suggest that mimicry is affected by the social dynamics of an interaction (Chartrand & Lakin, 2013). In experimental paradigms, participants tend to mimic their interaction partner and like their interaction partners more if they mimic them back (Chartrand & Bargh, 1999). Moreover, if participants want to affiliate with their interaction partner, and especially when they have failed to affiliate during a preceding cooperation task, they mimic their interaction partners more (Lakin & Chartrand, 2003; Lakin et al., 2008). The opposite has also been documented; if participants do not like their interaction partner, they tend not to mimic them but instead seem to decrease their own executions of the behaviors performed by their disliked interaction partner (Yabar et al., 2006). This "negative mimicry" (Yabar et al., 2006) is in line with the notion that typical, affiliative interactions entail a certain level of behavioral mimicry, implying that deviations of too much or too little mimicry can have disaffiliative effects (Kouzakova, Karremans, van Baaren, & Knippenberg, 2010; Kouzakova, van Baaren, et al., 2010; Leander et al., 2012). Consequently, the increase in mimicry to affiliate and overcome exclusion on the one hand and the negative mimicry of disliked individuals on the other hand suggest that mimicry, and the lack thereof, subtly communicates (dis)affiliation during our daily interactions.

There is some evidence that young children already display behavioral mimicry. In three separate samples, children performed meaningless behaviors, such as cheek scratching and mouth rubbing, significantly more while observing a female video model do so than during a baseline period. While 3-year-olds'

mimicry was unaffected by social manipulations (van Schaik & Hunnius, 2016; van Schaik et al., 2013), 4-6-year-olds primarily mimicked in-group models (van Schaik & Hunnius, 2016). This developmental pattern suggests that during early childhood the propensity to mimic becomes more and more a product of the social dynamics of the interaction. It has been put forth that the development of mimicry into the implicit social behavior found in adult interactions is a function of a broadening social understanding and improvements in inhibitory control (van Schaik & Hunnius, 2016).

As children's social experiences increase during early childhood, so too does their social understanding. This is not only reflected in classic measures of social perspective taking but is also evident from children's socially selective copying behaviors and sensitivity to social norms. A range of false-belief tasks show steady improvement between the ages of two and six (Hughes & Ensor, 2007; Wellman & Liu, 2004). Individual differences in performance on such social perspective taking tasks are largely stable, and task performance predicts later peer acceptance (Caputi, Lecce, Pagnin, & Banerjee, 2012; Hughes & Ensor, 2007). Awareness of the social dynamics of interactions is further evident in children's imitative interaction behaviors. Similar to adult mimicry findings, 5- to 6-year-olds imitate in-group members more after being excluded from this group (Watson-Jones et al., 2016). Correspondingly, particularly 5-year-olds, but to a lesser degree 4-year-olds, display contrasting instead of imitative behaviors in response to out-group members' behaviors (Oostenbroek & Over, 2015). Children's explicit understanding of social norms also becomes more influential on their own behaviors with age. While toddlers are already sensitive to receiving an unequal share of resources and tend to equally share resources themselves when all else is equal, it is not until middle childhood that children can overcome preferences for resources and interaction partners to enforce the social norm of sharing on their own sharing behavior (Chernyak & Sobel, 2016; LoBue, Nishida, Chiong, DeLoache, & Haidt, 2011; Smith et al., 2013). In this regard, increasing social understanding might be related to the emergence of socially sensitive interactive behaviors such as mimicry. Indeed, in adults, mimicry is related to social understanding, as individuals who score higher on perspective taking mimic more (Chartrand & Bargh, 1999; Chartrand & Lakin, 2013).

Alongside a growing social understanding, young children are increasingly able to regulate their behaviors. A spectrum of inhibitory control tasks show significant improvements between the ages of 2 and 6 years of age (Carlson, 2005). This increasing inhibitory control seems to directly influence children's interaction skills, as during joint actions inhibitory control is related to children's accuracy in turn-taking (Meyer et al., 2015). With respect to behavioral mim-

icry, these developmental improvements in inhibitory control could be related to the social sensitivity of children's mimicry that is seen in 4- to 6-year-olds but not 3-year-olds (van Schaik & Hunnius, 2016). Hence, it could be the case that, given a level of social understanding that ensures that a child is sensitive to the social interaction context in general, a child's inhibitory control helps her regulate mimicry such that she is socially selective in who she mimics.

Taken together, behavioral mimicry is a facet of social interactions through which (dis)affiliation is communicated. Although there is evidence to suggest that mimicry develops during early childhood, it is unclear how social-cognitive factors contribute to the emergence of social mimicry. In the current study, we aimed to investigate naturalistic social mimicry during early childhood and the influences of inhibitory control and social understanding on children's mimicry. To this end, we designed a partially live behavioral mimicry paradigm amicable to the use of a social manipulation.

The setup entailed two female experimenters; the first shared one of two stickers with the child (i.e. the sharer) while the second decided to keep both stickers for herself (i.e. the keeper). After this social manipulation, children observed a video in which each experimenter told the child a story. Stories were used as a means of maintaining the children's visual attention towards the experimenters while minimizing the use of objects that could distract children away from the experimenter. This combination of live interaction and videos was beneficial for several reasons. The social manipulation was live so that it would be experienced as a meaningful interaction for the children and to guarantee that children knew that the experimenters were real individuals, making affiliation possible. The videotaped stories ensured that experimenters did not implicitly act more friendly to some children, controlled the amount of behaviors children were exposed to, and kept the duration of the coded mimicry period constant.

To test mimicry, two groups of participants were used. The experimental group observed the experimenters display behaviors while telling the stories, whereas for the control group the experimenters told stories without displaying these behaviors. This between-participants baseline method ensured that experimental order did not influence behavior prevalence, as the timing of when during the experiment separate baseline and experimental periods occur could influence behavior prevalence due to extraneous factors such as fatigue or initial shyness. Also, arousal during social interactions, particularly in the context of a social manipulation, could be higher than during nonsocial baselines (Yabar et al., 2006), hence this method kept social arousal constant across baseline and experimental measures. Furthermore, a between-participants design also ensured that participants could not experience a contrast of a to-be-mimicked

behavior being absent or present during the stories as would be the case in a within-participants design (Emanuel, 2012).

Social understanding was measured with the short version of the Children's Social Understanding Scale (CSUS) filled in by the accompanying parent (Tahiroglu et al., 2014). This scale was selected as it encompasses multiple aspects of social understanding, such as understanding emotions and desires, and concerns everyday examples making it more ecologically valid than a standard verbal false-belief task (Tahiroglu et al., 2014). Inhibitory control was assessed at the end of the experiment using the day-night task (Carlson, 2005; Gerstadt, Hong, & Diamond, 1994; Montgomery & Koeltzow, 2010). The day-night task requires participants to inhibit a prepotent response, for example the association between the sun and the concept day, in favor of an opposing response, saying day when seeing a moon picture (Gerstadt et al., 1994).

This design allowed us to test four hypotheses. First, it was hypothesized that, overall, children would display behavioral mimicry, as evident in higher behavior occurrences in the experimental group than in the control group. Second, it was expected that children would mimic sharers but not mimic, or negatively mimic, keepers. Third, the selectivity of children's mimicry (i.e. the difference between mimicry of the sharer and mimicry of the keeper) was hypothesized to be a product of inhibitory control, given a certain level of social understanding. Fourth, social understanding was expected to be related to children's overall mimicry.

METHOD

Participants

Thirty-two 5-year-olds (60.6 to 61.8 months; 15 girls) participated in the experimental condition. Two children were excluded prior to data analysis: one because the child's hands were not visible in the video recording and one because the child had a cast on his arm. An additional two participants' data was excluded during data preparation (see Measures section below). The final experimental group consisted of 28 children (Age: $M = 61.29$, $SD = 0.37$ months; 14 girls). However, three children's day-night scores were scored as missing: one because the child did not want to complete the task, and two due to parental help during the task.

Twenty-nine 5-year-olds (60.4 to 61.9 months; 15 girls) participated in the control condition. Five were excluded prior to data analysis; one child had put the sticker on their hand and played with it throughout the session confounding

the coding of the hand rub behavior, one had to use the restroom during the story session, one was unable to hear the stories well, one child's behavior could not be coded due to a corrupt video file, and for one child it could not be ruled out that they were mimicking their parent throughout the session. One additional participant's data was excluded during data preparation (see Measures section below). The final control group consisted of 23 children (Age: $M = 61.03$, $SD = 0.10$ months; 10 girls).

Participants were recruited from a database of volunteer families representative of the middle-sized Western European city the research was conducted in. All parents gave signed informed consent before participation. Children were thanked for their participation with either a children's book or 10 euros. Additionally, children received a sticker during the social manipulation that they could keep.

Materials

Experimenters. Two female experimenters ran the experiment for all participants (see Figure 1). To maximize children's ability to identify which experimenter was which, one experimenter always wore a white T-shirt, had her hair loose, and sat on the left side of the table (from the child's point of view), while the other always wore a black T-shirt, had her hair in a braid, wore glasses, and sat on the right.

Lab setup. The child sat across from the two experimenters and their parent sat next to them to the side. A projector was setup up such that videos could be projected on a white wall directly behind where the experimenters sat. Speakers were placed on the ground below the projected area. Each experimenter had a small box with two stickers and a laminated photograph of themselves on their side of the table. Parents were provided with a clipboard with an overview of the procedure and the CSUS. Two unobtrusive synchronized cameras recorded the session and could be monitored in an adjacent room.

Stimulus videos. The stimulus videos, displayed via the projector during the experiment, showed the two experimenters sitting side-by-side in the same manner as during the live interaction (i.e. each experimenter on her respective side with the same attire and appearance; Figure 1). Two types of videos were recorded. In the 'introduction videos', one of the two experimenters announced, "Hey, we are sitting here now." There were two versions of the introduction video, one in which the experimenter on the left spoke and one in which the experimenter on the right spoke. Both experimenters were smiling and looking towards the camera. In the 'story videos', the experimenters took turns telling a "Jip and Janneke" story by Annie M. G. Schmidt. The experimenter on the left

always told a story about sewing seeds and the experimenter on the right told a story about picking flowers. While one experimenter told the story, the other experimenter looked at her. Both stories were supplemented with four pictures that the storytelling experimenter held up to the camera in order to maintain children’s attention.



FIGURE 1 | Still frames from story videos. A: Experimental condition: the experimenter on the left is performing the hand rub behavior while telling her story and the experimenter on the right is performing the face rub. B: Control condition.

In the experimental condition, each experimenter carried out one behavior nearly continuously (as is typical of adult mimicry experiments, see Figure 1.A; e.g. Chartrand & Bargh, 1999; Cheng & Chartrand, 2003; Lakin & Chartrand, 2003; Lakin et al., 2008), both while telling the story and while listening to the other tell the story. In other words, both behaviors were shown throughout the story session, one by one experimenter (e.g. face rubbing) and the other by the other experimenter (e.g. hand rubbing; counterbalanced). The face rub consisted of the experimenter freely rubbing her hand over her mouth and chin and scratching her cheek (right and left hands were used interchangeably). The hand rub consisted of the experimenter rubbing her hands over one another, rubbing her wrists, and interlocking fingers. Behaviors were not carried out by either experimenter while the storytelling experimenter was showing a picture. In the experimental condition there were four versions of the story videos, as dictated by the four combinations of experimenter order (i.e. first or second) and experimenter’s behavior (i.e. face rub or hand rub); each participant observed one of these versions.

In the control condition, there were two versions of the story video to counterbalance across participants, as no behaviors were carried out (i.e. experimenter 1 tells story first, experimenter 1 tells story second; see Figure 1.B). On average, story videos were 5.5 min in duration, with each story taking up about half of that time.

Procedure

Upon arrival at the lab, the child drew a picture while the experimenters explained the procedure to the parents and showed interest in what the child was drawing by asking questions and complimenting their work. Following this warm-up period, the so-called sticker game (i.e. social manipulation) started. One experimenter (counterbalanced) would open a small box on their side of the table, take out two stickers, and exclaim, "Look! I have two stickers! Wow, these are nice. Look a [picture on sticker, e.g. cat] and a [picture on sticker, e.g. dinosaur]. Wow, these are nice. Do you like them too?" At this point, the child was given the opportunity to answer (all children indeed said they liked the stickers). The experimenter then said, "Well, because I like them so much, I will share them with you. Which one would you like?" Once the child had chosen a sticker, the experimenter put the other sticker down in front of herself and said, "Look, now we both have a sticker!" The other experimenter then repeated this procedure, with the exception that, after asking the child if he/she liked the sticker the experimenter said, "Well, because I like them so much, I will keep both stickers for myself." The experimenter proceeded to place both stickers in front of her.

Next, the 'sharer' gave a little box to the child to put their sticker in so that the child would not have the sticker in her hands during the rest of the experiment. Both experimenters also put their stickers back into their boxes. The sharer then announced that she would have to go to the other room but that she would leave a photograph of herself behind and proceeded to place the photograph facing the child on the table before leaving. After the sharer got up, the 'keeper' did the same.

Once the experimenters had left, the parent asked the child, "If you could play another game with one of these two ladies, with who would you want to play? Her or her?" Parents were free to point to the photos of the experimenters and had been instructed to repeat the question until the child made a choice.

Following this, the introductory video was played via the projector. Parents were instructed to move their child's chair back from the table at this point. This was done so that children would not be leaning on the table nor be able to grasp objects on the table, and to ensure that children's hands would be visible for offline coding. Once the child was situated, the story video was played. Which experimenter spoke in the introductory video, which experimenter first started to tell their story, and, in the experimental condition, which behavior was carried out by which experimenter, was counterbalanced across participants. Parents were asked to fill in the CSUS while their child watched the story videos.

After the stories, the sharer came back into the room and carried out the day-night task with the child. The session was concluded with the keeper also coming back into the lab. In a funneled debriefing, the keeper asked the child if she had noticed anything while watching the videos and, in the experimental condition, whether she had noticed if the experimenters carried out face rubs or hand rubs. To ensure that the child could identify the experimenters, the keeper asked from whom they had gotten a sticker and from whom they had not (all participants were indeed able to correctly identify the sharer and keeper). The keeper then apologized for not sharing, saying that it was not a very kind thing to do and offered to make up for it by letting the child choose a gift (i.e. the children's book or money).

Measures

Video recordings were used to code children's visual attention, face rubs and hand rubs during the story session, which was performed blind to sharer identity and sharer's and keeper's behaviors. For both groups, the percentage of the story time that a child carried out a behavior was calculated for both behavior types separately. Before further measure calculations, behavior percentages were checked for outliers above 3 SDs from the mean per behavior, per group. This led to the exclusion of two participants from the experimental group and one from the control group.

Behavior measure calculations are displayed in Table 1. Within the experimental group, each child's behavior percentages (i.e. face percent and hand percent) were divided by the control group's average behavior percent of the corresponding behavior, providing behavior ratios. The same was done for the sum of both behaviors to obtain a measure of total mimicry. If a child from the experimental group's ratio is above 1, the child performed the behavior(s) more than the control group did on average, while if it is below 1, the child performed the behavior(s) less than the control group's average. The calculation of behavior ratios allowed for comparisons within the experimental group while correcting for possible general differences in face rubbing and hand rubbing prevalence (as measured in the control group). In other words, this allowed us to collapse across the counterbalancing of face and hand behaviors to test the difference in the mimicry of the sharer versus the keeper. A measure of selective mimicry was calculated per experimental participant by subtracting the keeper ratio from the sharer ratio, providing a difference score indicating how much more (positive values) or less (negative values) the sharer was mimicked than the keeper. Assumptions of statistical tests were checked first and non-parametric

analyses were used when needed. All reported p-values are two-tailed unless stated otherwise.

TABLE 1 | Behavior measure calculations

Measure	Group	Calculation	Comparison
<u>Behavior Percentages</u>	experimental control	time spent carrying out behavior / time watching story videos	Hypothesis 1: experimental vs. control group
Face rub percent			
Hand rub percent			
<u>Behavior Ratios</u>	experimental	Behavior % / control group's mean behavior%	Intermediate measure
Face rub ratio			
Hand rub ratio			
<u>Social Ratios</u>	experimental	behavior ratios split into sharer's and keeper's behaviors (dependent on counterbalancing)	Hypothesis 2: sharer vs. keeper ratios
Sharer ratio			
Keeper ratio			
<u>Selective Mimicry</u>	experimental	sharer ratio - keeper ratio	Hypothesis 3: relation inhibitory control and selective mimicry
<u>Total Mimicry Ratio</u>	experimental	Σ behavior %s / control group's mean Σ behaviors %s	Hypothesis 4: correlation social understanding and total mimicry

Control Comparisons

To ensure that the two groups of participants did not differ in social-cognitive development, the inhibitory control and CSUS scores were compared. There were no differences between the experimental and control groups in their day-night task score nor their CSUS score ($ps > .20$).

The time children spent watching the videos was near ceiling in both the experimental and control groups, as on average children watched respectively 99.14 and 98.45 percent of the story session. In the experimental group, there was no significant difference between how much of the sharer's story children watched and how much of the keeper's story ($p > .25$). This is an important comparison as it indicates that potential differences in the mimicry of the sharer and keeper were unlikely to be a simple effect of having seen one storyteller's behavior more than the other's. The control group, though, looked significantly longer at the keeper's story ($M = 99.63$, $SD = 1.30\%$ of story attended) than the sharer's story ($M = 97.28$, $SD = 5.85\%$ of story attended), $t(22) = 2.17$, p

= .04. Yet, the primary reason for conducting this control analysis, namely to ensure that one storyteller's behavior was not observed more than the other's, does not hold for this group as they did not observe the storytellers perform behaviors. Additionally, all behavior percentages were calculated by dividing the total duration of behaviors that started while the child was attending by the duration of time that the child was attending to the screen, thus eliminating the influence of looking time on the control group's behavior percentages.

Binomial tests were used to test whether the social manipulation affected children's explicit preference to play with either the sharer or the keeper. In both groups, the observed proportions of children who selected the sharer (experimental group = .59; control group = .41) and keeper (experimental group = .41; control group = .59) did not differ significantly from chance (i.e. 50%; $p_s > .40$).

RESULTS

To test the first hypothesis that the experimental group mimicked the storytellers, the experimental group's face rubbing and hand rubbing percentages were compared with those of the control group. For both behaviors, the control group performed the behaviors for a significantly higher percentage of time than the experimental group and these effects were of a medium effect size (see Figure 2.A). A Mann-Whitney U test revealed that the experimental group ($Mdn = 0.34\%$) rubbed their face significantly less than the control group ($Mdn = 1.61\%$), $U = 209.5$, $z = -2.20$, $p = .028$, $r = .31$. Likewise, hand rubbing was significantly lower in the experimental group ($Mdn = 4.04\%$) than in the control group ($Mdn = 10.75\%$), $U = 200$, $z = -2.33$, $p = .02$, $r = .33$. This effect remained significant for both behaviors when the ten children of the experimental group who reported having noticed one or both of the behaviors were excluded; face rubbing: $U = 119$, $z = -2.370$, $p = .018$, $r = .37$, hand rubbing: $U = 118$, $z = -2.36$, $p = .019$, $r = .37$. As an exploratory measure, face rubbing and hand rubbing percentages were compared within the control group to test for differences in the natural prevalence of these behaviors in 5-year-olds. A paired-samples t-test indicated that hand rubbing ($M = 12.32\%$) occurred significantly more often than face rubbing ($M = 2.88\%$), $t(22) = 3.97$, $p = .001$, $r = .65$.

The second hypothesis was tested within the experimental group; behavior ratios of the sharer's behavior were compared with those of the keeper to investigate social (negative) mimicry (see Figure 1.B). A Wilcoxon signed rank test indicated that, contrary to expectation, there was no significant difference

between sharer ratios ($Mdn = 0.07$) and keeper ratios ($Mdn = 0.30$), $z = -1.43$, $p = .153$, $r = .27$. Instead, sharer ratios ($z = -4.35$, $p < .001$, $r = .82$) and keeper ratios ($z = -3.24$, $p = .001$, $r = .61$) were significantly lower than 1, as tested with one-sample Wilcoxon signed rank tests. Thus, on a group level, both the sharer's and the keeper's behaviors were suppressed.

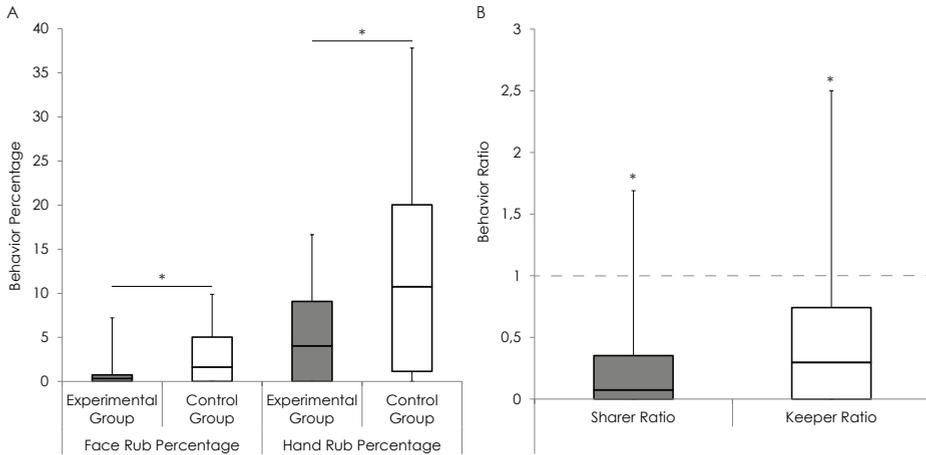


FIGURE 2 | Mimicry and social mimicry box plots. A: Experimental and control groups' face and hand rub percentages. Behavior percentages indicate the percentage of the story session that children performed the behavior. B: The experimental group's sharer ratio and keeper ratio. Behavior ratios indicate the proportion of the experimental group's behavior percentages relative to the control group's mean behavior percentage.

Third, the hypothesized effect of inhibitory control on selective mimicry (i.e. sharer minus keeper ratios) and the hypothesized moderation of this effect by social understanding were investigated using a linear regression with a moderator. A linear regression model with the day-night score as the predictor yielded a model that significantly predicts selective mimicry (Table 2). Adding social understanding as a moderator of inhibitory control's effect on selective mimicry did not significantly improve the model. The direction of the relation suggests that the better a child's inhibitory control, the smaller (i.e. more negative) the difference between sharer and keeper behavior ratios (Figure 3).

The fourth hypothesis entailed the relation between social understanding and how much children mimicked overall. There was a marginally significant positive correlation between children's score on the social understanding scale and the total mimicry ratio (i.e. the summed behavior percentages relative to the control group's behavior percentages) indicating that the higher children's social under-

standing, the more they performed the behaviors (Table 3). To investigate the specificity of the relation between social understanding and total mimicry, the correlation between inhibitory control and total mimicry was tested and found to not be significant ($p > .25$). Indeed, a comparison of the correlations (Lee & Preacher, 2013) indicated a near significant difference between the correlation of total mimicry and social understanding and the correlation of total mimicry and inhibitory control, $z = 1.63$, $p_{\text{one-tailed}} = .052$.

TABLE 2 | Regression model inhibitory control and selective mimicry

	B	SE B	β	R ²
Step 1				
Constant	0.884	0.457		
Day-Night	-0.089	0.036	-.460*	0.211
Step 2				
Constant	0.865	0.457		
Day-Night	-0.088	0.036	-.460*	
Social Understanding Moderator	0.249	0.245	.188	0.247

* $p = .021$; Step 2: $\Delta R^2 = 0.035$, $p = .32$

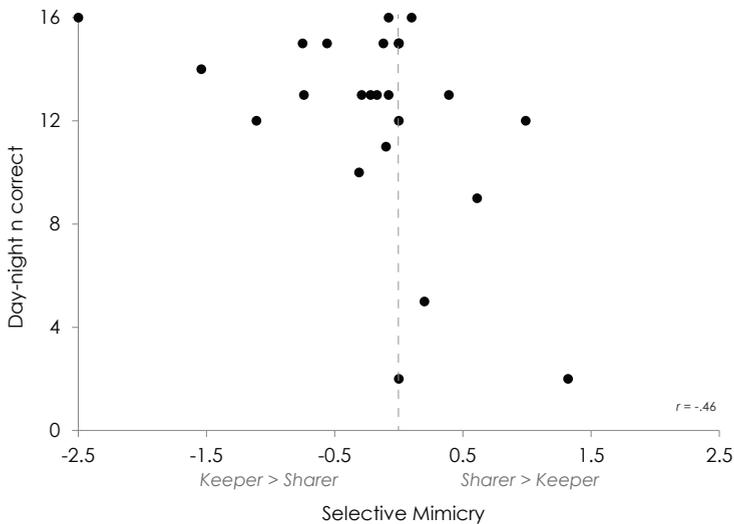


FIGURE 3 | Relation between inhibitory control and selective mimicry.

TABLE 3 | Correlation matrix of developmental factors and total mimicry ratio

	Total Mimicry Ratio	Day-Night
CSUS (n = 28)	.328*	.039
Day-Night (n = 25)	-.134	-

Spearman's rho, * $p < .088$

DISCUSSION

The aims of this study were to investigate 5-year-olds' social behavioral mimicry in a naturalistic interaction and to explore the developmental factors contributing to this behavior. After a live social interaction in which a child interacted with a kind individual, an experimenter who shared a sticker, and an unkind individual, an experimenter who kept stickers for herself, children observed these two experimenters each tell a short story. During the story session, the experimental group observed the experimenters rub their face and hands, while the control group did not see these behaviors. Following the stories, children completed the day-night task as a measure of inhibitory control. Parents' evaluations of their child's social understanding were collected through the CSUS. There were four comparisons of interest: (1) behavior percentages in the experimental versus control groups to test for (negative) mimicry, (2) sharer versus keeper ratios to examine social mimicry effects, (3) the influence of inhibitory control on children's selective mimicry of the sharer over the keeper, and (4) the relation between children's social understanding and how much they (negatively) mimicked overall.

First, we investigated whether children displayed behavioral mimicry overall. The percentage of time children spent face rubbing and hand rubbing was compared between the two groups. Significant suppression was found for both behaviors; children in the experimental group, those who observed the experimenters perform behaviors, performed face and hand rubbing less than the control group. Importantly, this effect cannot be explained as a consequence of participants noticing the behaviors, as the findings held when the participants who reported noticing the behaviors during the debriefing were excluded from the analyses. Thus, overall, there was evidence for negative mimicry, with children seemingly refraining from these behaviors when they observed others carry them out.

The medium effect sizes of this suppression suggest that the findings are not spurious; instead, the sole difference between the experimental and control groups' experience during the experiment, namely the presence or absence of

the experimenters' behaviors during the stories, seems to have caused a considerable difference in the two groups' behavior. Yet, it is unclear why there would be an overall decrease in behaviors, since previous decreases in mimicry have been related to the social characteristics (Yabar et al., 2006). It could be the case that the presence of the to-be-mimicked behaviors subtly influenced the "interaction" dynamics in the experimental group to a degree of decreasing affiliation and thereby reducing affiliative mimicry. Live interactions are in constant flux, with both partners mutually adjusting to the other (Kendon, 1970). In this video-based design, though, the storytellers could not act contingently on the children's behavior in any way. Resembling a context with too little mimicry (Leander et al., 2012), this lack of any contingency might have served as a disaffiliative signal towards the child (see Catmur & Heyes, 2013), possibly reducing their mimicry behaviors as a result. Yet, this speculative interpretation warrants further investigations, as previous mimicry studies have successfully utilized video-based methods before (e.g. Emanuel, 2012; Lakin & Chartrand, 2003; van Baaren, Horgan, Chartrand, & Dijkmans, 2004; Yabar et al., 2006).

Alternatively, the suppression effects might have been a consequence of the high behavior prevalence in the control group. Here, the storytellers did not perform any manual actions and, as was the case for the experimental group, they could also not act contingently on children's behaviors through other means. Perhaps this relatively motionless storytelling contrasted too much with the dynamic live sticker game preceding the stories, making the children uncomfortable, causing them to fidget more, and, hence, thereby also perform the target behaviors more. However, past adult work in support of this design contradicts this point. In a nonsocial one-minute baseline preceding the experiment, behavior rates were three times higher than those of a matched baseline group like that used in the present study (Emanuel, 2012).

Interestingly, hand percentages were higher than other behavior percentages in a previous developmental mimicry study. In that study, 4- to 6-year-olds' baseline and mimicry percentages of different face rubbing and non-manual behaviors combined was in the order of a few percent (van Schaik & Hunnius, 2016), much like the face rubbing found in the present study. This low occurrence of the behaviors matches the lower bound of adult studies (e.g. Cheng & Chartrand, 2003). Yet, in the present study, hand rubbing percentages were significantly higher than face rubbing percentages in the control group. These differences in behavior percentages indicate the importance of behavior type; from the control group's behaviors, it seems that face rubbing is only occasionally performed by 5-year-olds while hand rubbing is a more natural behavior in a story telling situation. This suggests that mimicry studies should utilize behaviors that children

typically carry out in order to establish whether children mimic (or suppress) these behaviors during interactions. A previous adult study demonstrated the usefulness of such an approach. As opposed to the classic face touching and foot bouncing behaviors used in the majority of the mimicry literature, different behaviors were selected. While no mimicry of behaviors chosen purely on the basis of participant self-reports was found, cheek rubbing and ear touching selected based on participant observation did result in significant mimicry effects (Emanuel, 2012). Thus, although contrary to expectations, the suppression effects found in this study provide meaningful information regarding children's social interaction behaviors. Future studies should investigate which behavior types are applicable to a developmental demography.

The second comparison tested whether children's (negative) mimicry was affected by the social manipulation. It was hypothesized that children's behavior ratios for the sharer would be significantly higher than those for the keeper. In addition, it could be predicted that particularly sharer ratios would be higher than 1, as this would indicate more behavior in the experimental group than in the control group (i.e. mimicry), while keeper ratios could be lower than 1, indicating less behavior in the experimental than control group (i.e. negative mimicry). However, no difference was found between sharer and keeper ratios. Moreover, both sharer and keeper ratios were significantly lower than 1, indicating that children suppressed their behaviors for both experimenters.

A negative mimicry effect has been previously documented in an adult study in which the more participants disliked the confederates the more negative mimicry they displayed. Yet, liked participants were mimicked (Yabar et al., 2006). In addition to the earlier discussed possible influences on total mimicry effects, the lack of group-level differences between the sharer and keeper in the present study could be due to the keeper's inconsistent behavior. During the warm-up period, the keeper and sharer interacted to an equal and positive extent with the child, and later, following the sticker game, the keeper appeared to cooperate with the sharer by sitting next to her and telling the child a story. This might have caused children to reason about why the keeper kept both stickers leading them to overlook this unkind act and still want to affiliate. It could also have lead children to feel ostracized by this otherwise kind individual thereby possibly increasing affiliation goals (e.g. Watson-Jones et al., 2016; Watson-Jones, Legare, Whitehouse, & Clegg, 2014). In these situations, children would hold affiliation goals with both the keeper and sharer, thus explaining why there was no difference in children's negative mimicry of the two experimenters.

Whereas the explicit liking measure did not show a significant preference for the sharer, this finding in itself does not necessarily indicate that the social

manipulation was not understood by the children. The phrasing of the preference measure, namely asking the child with whom they wanted to play if they could play another game, might have been interpreted differently in the context of this experiment than in previous experiments in which it was deemed understandable for children of this age (van Schaik, Endedijk, Stapel, & Hunnius, 2016). At the end of the experiment, several children reasoned that they selected the keeper to try to get the sticker from her, indicating that the question might have been interpreted as a repetition of the sticker game. Thus, the liking measure was not a sensitive measure of children's true preferences. Indeed, all children could correctly identify the keeper at the end of the experiment, so there is little reason for children not to have been sensitive to fairness, an effect demonstrated in several past studies (Chernyak & Sobel, 2016; LoBue et al., 2011; Paulus, Gillis, Li, & Moore, 2013; Smith et al., 2013). However, the lack of social effects on children's (negative) mimicry, as well as the overall negative mimicry effects, remains up for debate. It could be the case that the use of behavioral mimicry in interactions, and particularly its sensitivity to social dynamics, is still developing during early and middle childhood. Hence, whereas some strong social effects already influence mimicry on a group level at the age of five, such as group boundaries (van Schaik & Hunnius, 2016), more subtle or intricate social dynamics might only appear in implicit social interactive behaviors later during development.

Evidence in favor of a prolonged developmental trajectory of social mimicry comes from the third analysis, entailing the effect of inhibitory control on selective mimicry. Even though there were no statistically significant social effects on the group level, individual differences within the groups could still have affected children's selective mimicry. Accordingly, we investigated whether inhibitory control influences selective mimicry and whether this effect is moderated by children's social understanding. In a regression analysis, inhibitory control significantly predicted selective mimicry, but the addition of social understanding as a moderator did not improve the predictive power of the model. The model indicates that the more inhibitory control a child had, the more negative the difference between sharer and keeper ratios was. In other words, while children with lower inhibitory control would generally suppress the sharer's behavior less than the keeper's (i.e. mimic the sharer more), children with higher inhibitory control would overall suppress the keeper's behavior less than the sharer's (i.e. mimic the keeper more). This relation suggests that, if possible based on their inhibitory control, children influenced their behaviors in favor of the keeper, in line with the keeper-affiliation goals discussed above. Furthermore, these results

imply that using mimicry to display affiliation, particularly towards unkind others such as sticker keepers, requires some level of behavioral control.

Finally, there was a marginally significant correlation between social understanding and total mimicry in the hypothesized direction; the higher children's social understanding, the more behaviors they carried out. In other words, the children with higher social understanding scores were also generally the children who suppressed their behaviors less, and a few would even be said to have mimicked as their total mimicry ratios were above 1. This relation was specific to the CSUS score, as inhibitory control was unrelated to how much children mimicked overall. This is in line with the idea that a general understanding of social interactions and the individuals in those interactions is important for the display of affiliative behaviors. That is, it seems as if through increasing social experience and understanding, children's interactive behaviors become increasingly multifaceted. These results and those of the predictive relation of inhibitory control on the social sensitivity of mimicry suggest that distinct developmental factors influence the emergence of behavioral mimicry in children's social interactions and their specific social implementation of it.

Arguably, though, the range of the CSUS scores might have limited the strength of the effects of social understanding. The CSUS scale ranges from 1 to 4 but the lowest individual score in the present sample was 2.5 meaning that no participant scored in the lower half of the scale. This lack of spread might also have limited the statistical sensitivity of finding the hypothesized moderator role of CSUS on inhibitory control's influence on selective mimicry. Yet, interestingly, whereas typical false-belief tasks are related to inhibitory control (Carlson & Moses, 2001; Carlson et al., 2002; Hughes & Ensor, 2007; Mcalister & Peterson, 2013), there was no correlation between the CSUS and the day-night task in this study. Thus, this measure was successful in capturing a distinct developmental factor, though its range was limited. Future research should investigate individual differences and their effects on mimicry in more diverse samples and different age groups to better understand the relations identified in this study.

In conclusion, this study was designed to measure naturalistic social mimicry in young children and investigate the effects of developmental factors on mimicry's emergence. Only suppression, or negative mimicry, effects were found, regardless of the social identity of the interaction partner. On an individual level, though, inhibitory control predicted the amount of suppression of a sharer's versus keeper's behaviors. Additionally, social understanding was related to how much children mimicked overall. Thus, this study provides the first evidence that the social behavioral mimicry as seen in adults is the product of unique contributions of social and cognitive factors. Furthermore, the novel design presented

here provides a naturalistic yet controlled means through which to investigate behavioral mimicry from toddlerhood to middle childhood. This study opens the door for further investigations into the development of mimicry in early and also later childhood, the social contexts in which negative mimicry occurs, and the roles of behavior regulation and social understanding in the development of social interactive behaviors.

From early childhood onwards, individuals use behavior copying to communicate liking and belonging. This nonverbal signal of affiliation is especially relevant in the context of social groups and indeed both children and adults copy in-group more than out-group members. Given the societal importance of inter-group interactions, it is imperative to understand the mechanistic level at which group modulations of copying occur early in development. The current study was designed to investigate the effect of novel group membership on young children's motor behavior during a simultaneous movement-observation and -execution task. Four- to six-year-olds ($n = 65$) first gained membership to one of two novel groups based on their color preference and put on a vest in their chosen color. Subsequently, they were instructed to draw a straight line back-and-forth on a tablet computer that was concurrently displaying a stimulus video in which a model moved her arm congruently or incongruently to the child's instructed direction. In half of the stimulus videos the model belonged to the in-group, while in the other half the model belonged to the out-group, as identified by the color of her dress. The deviations into the uninstructed direction of the children's drawings were quantified as a measure of how much observing the models' behaviors interfered with executing their own behaviors. The motor interference effect, namely higher deviations in the incongruent trials than in the congruent trials, was found only for the out-group condition. An additional manipulation of whether the models' arms followed a biological or non-biological velocity profile had little effect on children's motor interference. The results are interpreted in the context of the explicit coordinative nature of the task as an effect of heightened attention towards interacting with an out-group member. This study demonstrates that already during early childhood, novel group membership dynamically influences behavior processing as a function of interaction context.

Chapter 5

Young Children's Motor Interference is Influenced by Novel Group Membership

J. E. van Schaik
H. M. Endedijk
J. C. Stapel
S. Hunnius

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Copying the behaviors of others occurs in many forms and plays a fundamental role in early social-cognitive development (Jones, 2009; Marshall & Meltzoff, 2014; Over & Carpenter, 2013; Paulus, 2014). Imitative play guides toddlers' everyday interactions with adults (Killen & Uzgiris, 1981) and peers (Eckerman & Peterman, 2004; Nadel, 2002). By the age of two, children's copying behavior is sensitive to the social availability of an adult model (Nielsen, 2006; Nielsen & Blank, 2011; Nielsen et al., 2008). This social sensitivity increases during early childhood (Over & Carpenter, 2012), as early preferences for similar others (Fawcett & Markson, 2010b; Haun & Over, 2015; Mahajan & Wynn, 2012) expand to encompass even arbitrary distinctions to demarcate groups (Buttelmann & Bohm, 2014; Dunham et al., 2011; Plötner et al., 2015). By the age of five, children mimic and imitate the behaviors of novel in-group members more than out-group members (van Schaik & Hunnius, 2016; Watson-Jones et al., 2016) and children use information about who copies whom to infer interpersonal affiliations (Over & Carpenter, 2015). These social effects of copying are not confined to childhood; the bi-directionality between copying those you like and liking those who copy you plays an important, often implicit role in adulthood (Chartrand & Lakin, 2013; Lakin, 2013). Hence, throughout the lifespan, but already starting during early childhood interactions, behavior copying is an essential means of communicating similarity and belonging (Heyes, 2013; Lakin & Chartrand, 2013; Over & Carpenter, 2012).

Underlying behavior copying is a neurocognitive coupling between observing and executing actions (Hamilton, 2015; Heyes, 2013; Molenberghs et al., 2009; Paulus, 2014). Ontogenetically, this 'mirror system' is shaped through both observational and active experience (Hunnius & Bekkering, 2014), making it a dynamic product of an infant's social environment (Heyes, 2010, 2013). Additionally, adult neuroimaging studies indicate that mirror system activation is modulated by social group membership. Mirror system and related activation triggered by the observation of actions has been found to be higher when the individual performing the action is an in-group member than an out-group group member, both for pre-existing and novel groups (Gutsell & Inzlicht, 2010; Molenberghs, 2013; Molenberghs et al., 2013; Rauchbauer et al., 2015).

However, the period in-between forming observation-execution associations during infancy and the mirror system's social sensitivity in adulthood is understudied. During the preschool years, the complexity of the social environment in which young children execute and coordinate their behaviors expands and social groups increasingly play a role in daily interactions (Eckerman & Peterman, 2004; Rubin, Bukowski, & Parker, 2006). Considering the social communicative function of copying behaviors reviewed above (Over & Carpenter, 2012), it is

imperative to understand social, and particularly group, modulations of copying on a mechanistic level during early childhood.

The motor interference task (Kilner et al., 2003) provides a versatile behavioral measure of observation-execution associations and their modulators. This task, though importantly not a direct measure of neural mirror system activation, is based on the notion that if observing a behavior and executing a behavior elicit overlapping representations, then doing both simultaneously could cause interference (Blakemore & Frith, 2005; Kilner et al., 2003). In the original study, participants moved their arm back-and-forth in a straight line either horizontally or vertically while concurrently observing a confederate performing the same movement in the congruent or incongruent direction. As expected, in the incongruent trials, participants' movement paths showed significant deviations into the direction of the uninstructed axis compared to both congruent trials and baseline trials without concurrent observation. Conditions with a robotic arm instead of a human confederate, though, elicited no interference in the participants' movements, which the authors interpreted as an indication that the task is especially sensitive to biological movements (Kilner et al., 2003).

In a developmental adaptation of the task, Marshall and colleagues (2010) had four-year-olds draw straight lines back-and-forth in either horizontal or vertical movements on a tablet computer screen using a stylus. At the same time, the screen was displaying a video of an adult female standing upright and moving her arm in either the congruent or incongruent direction. Like adults, the children in this study experienced motor interference (Marshall et al., 2010). As an initial exploration of the contribution of social factors on children's motor interference, the experiment was then repeated with two different models. In a within-participants design, 4.5-year-olds performed the task atop stimuli of either a same-aged boy or an adult male. The children experienced interference in the peer condition but the interference effect for the adult model disappeared. The authors place the findings in the context of a "like me" framework, emphasizing the social relevance of similar individuals (Marshall et al., 2010). Yet, it is unclear whether the "like me" effects were driven by social factors, since the peer was a possible friend, or biological factors, since the participants' own arm movements were more similar to the peer's movements due to their similar body proportions. Thus, although laying the groundwork, this study's results do not uniquely identify whether social factors influence young children's motor interference.

A following developmental study investigated the influence of movement profile more closely (Saby et al., 2011). In a similar tablet version of the task, 4- to 5-year-old children drew atop a bear puppet moving with a biological or

non-biological movement profile. The puppets had previously been animated or not during a story telling session. Contrary to expectations, though, motor interference was found for the biologically-moving previously-unanimated condition and non-biologically-moving previously-animated condition. The authors interpreted these results as an attentional effect of expectation violations that resulted from a mismatch between movement profile and animacy (Saby et al., 2011). Taken together, while these two developmental studies (Marshall et al., 2010; Saby et al., 2011) demonstrate the usability of the task with young children, the data are inconclusive as to the distinct influences of social and biological factors on children's motor interference.

The current study was designed to investigate the influences of social and biological factors on young children's motor interference more directly. Importantly, given the central role of social groups in young children's copying behaviors as reviewed above, as well as the aforementioned evidence suggesting a specific influence of social groups on adults' mirroring, we implemented a novel group manipulation. This provided a developmentally relevant manipulation and allowed us to measure the sensitivity of copying mechanisms to group processing effects without confounding the groups with past group experience or familiarity (Cikara & Van Bavel, 2014). By explicitly labeling group belonging and exposing the children to repeated interactions (i.e. trials) with in- and out-group models, the groups remained salient throughout the experiment. Additionally, by independently manipulating the movement profile (i.e. biological vs. non-biological) of in- and out-group models, we could isolate the influence of biological factors. Consequently, a 2 (congruency) by 2 (group membership) by 2 (movement profile) within-participants design was used.

It was expected that the motor interference effect would be replicated, by finding higher deviations into the uninstructed drawing direction in incongruent than congruent conditions. Also, interactions of both group membership and movement profile with congruency were expected. Observing in-group members was hypothesized to lead to greater interference effects than observing out-group, in line with higher copying rates of in-group than of out-group members (van Schaik & Hunnius, 2016). Following the adult motor interference literature (Kilner et al., 2007), it was hypothesized that biological movements would lead to more interference than non-biological movements. Finally, an interaction between congruency, movement profile and social group was expected in the direction of in-group biological trials showing the most interference.

MATERIALS AND METHODS

Participants

Seventy children (35 female) participated at two primary schools in the Netherlands. Two children did not complete the experiment. The data of 3 children was at two or more standard deviations from the mean (see also Data preparation) and was excluded from the final analyses. The final sample consisted of 65 4- to 6-year-olds ($M = 63.85$, $SD = 7.27$ months; 33 female). Signed informed consent was acquired from the guardian prior to participation. The schools could choose their preferred type of compensation: one school opted for each child receiving a sticker post-participation and the other school opted for a book voucher for the classrooms. This research was approved by the local social science faculty's ethics committee.

Stimuli

Stimulus videos displayed one of three female models (A, B, and C) from the waist up. The baseline stimulus (used for both the practice trials at the beginning of the experiment and baseline trials halfway through the experiment, see also Procedure) consisted of a video recording of model A wearing a green dress and standing still. In this manner, the baseline stimulus only differed from the experimental stimuli in the absence of arm movements, thus controlling for other factors such as body sway. In the experimental stimuli, the model (B, C; Figure 1) was wearing a blue or red dress. The model moved her arm vertically or horizontally back and forth. The biological movement stimuli were recorded at 25 frames per second. Loops (consisting of one back-and-forth movement) were selected for their straightness and how well they matched the other model's and direction's (i.e. vertical and horizontal) speeds. These loops were then repeated back-to-back such that one stimulus video showed 10 repetitions of the loop (note: this was also done for the baseline stimulus with a segment of 1.5 sec). The non-biological movement stimuli consisted of compiled photographs (frame rate = 25) in which the model's arm did not follow a typical biological velocity profile of slowing down at the returning points. Instead, the model's arm position shifted 10 degrees between every two pictures, resulting in a triangular velocity profile. Stimulus videos lasted on average 16.6 s (range 15.9-18.0). The models' dress colors (i.e. blue and red) were digitally edited, such that a full counterbalancing of model identity (i.e. models B and C) and color was possible.

Both stimulus display and the acquisition of data were performed with Presentation software (www.neurobs.com) on a tablet computer (Asus Eee Slate). The stimuli were cropped to be square (720 x 720 pixels; 146 x 146 mm on the

tablet screen). A hard plastic sheet with an opening overlaying the area of the screen where the videos were played was placed over the tablet screen, to limit the area on which children could draw to precisely the square dimensions of the video. The stylus' position on the screen was acquired at 100Hz.

Procedure

At the start of the experiment, the child was asked to draw a picture in Microsoft Paint in order to familiarize her with the stylus and tablet computer. Once the child had finished the drawing (or after 2 min), the experimenter started the experiment on the tablet computer. First, the colors red and blue appeared on the left and right sides of the screen (counterbalanced), and the child was asked to tap the stylus on the color they liked more (49% of the sample chose blue). The experimenter congratulated her on her choice and told her that she now belonged to that group. The child was given a vest to wear in the chosen color and the experimenter emphasized the group membership by exclaiming, "Wow! Now you are completely [chosen color], great!"

A practice session followed in which the baseline stimulus was shown twice, once as a horizontal practice and once as a vertical practice (order counterbalanced). The practice trials and all subsequent experimental and baseline trials followed the same procedure; before each stimulus, the screen was black while the experimenter instructed the child to draw a straight line back-and-forth either from side to side (horizontal) or top to bottom (vertical). The experimenter ensured that the child was holding the stylus at an appropriate starting position prior to starting the stimulus video (e.g. on the top or bottom of the screen for vertical trials, or at the left or right side of the screen for horizontal trials). Children were instructed to draw for the duration of each video (i.e. on average, 16.6 s of drawing per stimulus).

Following the two practice trials, the experimenter introduced the child to the two group models. A neutral picture of each model was shown for 7 s, accompanied by the experimenter's explanation, "Look! She (also) belongs to the [color] group. She is (also) wearing [color] clothes." The child was then informed that she would be seeing videos of these models and would have to draw lines like in the practice trials.

During the experimental trials, the experimenter instructed the child as for the practice trials; the experimenter instructed which direction to draw in and ensured the child held the stylus at an appropriate location while the screen was still black before each stimulus video started. The factors congruency (congruent vs. incongruent), movement profile (biological vs. non-biological), and group membership (in-group vs. out-group) were fully balanced within each child's ran-

domization of experimental trials (i.e. 8 trials). Whereas direction drawn was counterbalanced within participants, direction observed was counterbalanced across participants; each child drew half of their trials horizontally and half vertically, but always saw either vertical or horizontal videos.⁵ Halfway through the experimental trials (i.e. after 4 trials), the child took a break from working on the tablet by playing a game of Memory for a few minutes. After the break, two baseline trials (i.e. one vertical and one horizontal; order counterbalanced) were performed using the baseline stimulus following the same procedure as the practice and experimental trials. This was followed by the remaining 4 experimental trials.

At the end, explicit preferences were measured by showing the neutral pictures of the two models on either side of the screen. The experimenter asked two questions in a randomized order (question 1: Who do you like more?; question 2: Who would you like to play with?) and the child responded by tapping the picture of the model she preferred. Before bringing the child back to the classroom, the experimenter thanked the child and emphasized that because the game was over, the groups no longer mattered.

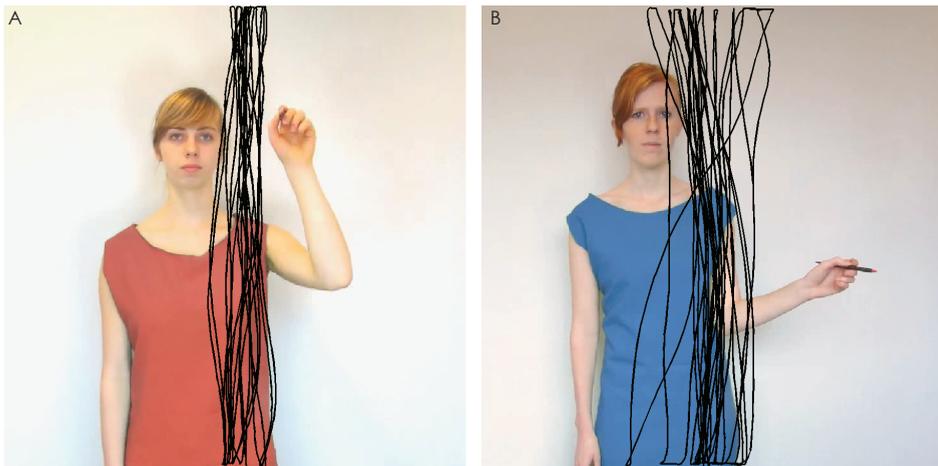


FIGURE 1 | Still frames of two stimulus videos illustrating different conditions. An example participant's drawings from a congruent (A) and incongruent (B) trial is overlaid in black. Note: the stylus did not leave a line on the screen during the experiment.

⁵ In a pilot, a full counterbalancing of models' movement direction (i.e. 16 trials) proved too long in duration for this age group.

Data Preparation

Motor interference was measured per trial as the standard deviation of all the sampled locations where the screen was touched in the uninstructed axis throughout the trial (Marshall et al., 2010; Saby et al., 2011). To account for individual variability in drawing ability, this was divided by the same measure (i.e. the standard deviation in the uninstructed axis) from the corresponding (i.e. horizontal or vertical) baseline trial, resulting in a 'deviation ratio'. Across participants, baseline outliers were first calculated per direction drawn at two or more standard deviations from the mean. Subsequently, outliers in the deviation ratios were calculated per condition per direction drawn also at two standard deviations. Outlying trials were excluded on a trial-by-trial basis and only 3 participants did not contribute any trials to the analyses.

RESULTS

First, the efficacy of the social group manipulation was tested. Explicit preferences were analyzed with a binomial test per question. The proportion of children who chose their in-group model in response to the question who they would like to play with (observed proportion = .70) was significantly higher than would be expected by chance (i.e. 0.50; $p = .002$). In response to the question regarding which model the children liked more, the proportion of children who chose their in-group model did not differ from chance (observed proportion = .54, $p = .615$). As a control, a chi-square analysis verified that the models were counterbalanced across participants in representing in- and out-group members ($p > .250$).

A linear fixed-effect model by means of maximum likelihood estimation was used. The model was performed on the deviation ratios with the factors congruency, social group, and movement profile (full-factorial; Figure 2) and direction drawn as a covariate. There was a significant main effect of congruency, $F(1, 385.81) = 17.12, p < .001, r = .21$, with deviation ratios in the incongruent conditions ($M = 1.21, SE = .031$) being higher than in the congruent conditions ($M = 1.05, SE = .024$). No main effects of movement profile nor social group were found. Conversely, there was a two-way interaction between congruency and social group, $F(1, 389.36) = 7.24, p = .007, r = .14$, and a three-way interaction between congruency, movement profile and social group, $F(1, 396.72) = 4.10, p = .044, r = .10$.

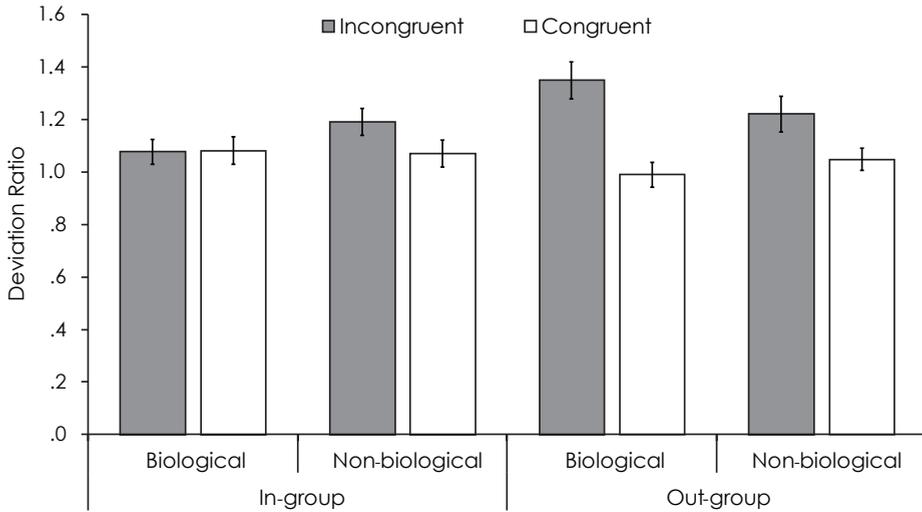


FIGURE 2 | Mean deviation ratios per condition. Deviation ratios were calculated by dividing the standard deviation in the uninstructed direction by the standard deviation in the instructed direction from the corresponding baseline trial. Error bars indicate standard errors of the mean.

The interactions were tested further by repeating the analysis for the in-group and out-group conditions separately. For the in-group analysis there were no significant effects (congruency main effect: $p = .143$, all other $ps > .250$). The out-group analysis indicated a main effect of congruency, $F(1, 195.43) = 19.42$, $p < .001$, $r = .30$. Deviation ratios for incongruent out-group trials ($M = 1.28$, $SE = .049$) were significantly higher than those for congruent out-group trials ($M = 1.02$, $SE = .032$). The interaction between congruency and movement profile did not reach significance ($p = .175$, $r = .10$). With respect to the original three-way interaction, Figure 2 and the lack of any effects within the in-group suggest that this interaction was partially driven by the higher difference between incongruent and congruent trials in the biological out-group conditions (difference = .339) than in the non-biological out-group conditions (difference = .178). In sum, significant interference effects were found in the out-group condition but not in the in-group condition and no significant effects of movement profile were found.

DISCUSSION

In this study, the effects of novel group membership and movement profile on 4- to 6-year-olds' motor interference were investigated. Participants performed

back-and-forth movements either congruently or incongruently with respect to an in-group or out-group model's movement direction. The expected motor interference effect was replicated, as incongruent conditions differed significantly from congruent conditions. This effect was only present for the out-group condition and did not occur for the in-group condition. Although there was also an interaction with movement profile, the effect of whether the models moved biologically or non-biologically was minimal.

An explicit measure indicated that the group allocation was effective in eliciting an in-group preference. Whereas the abstract question regarding liking did not show an in-group bias, the concrete question of whether children would like to play with the in-group or out-group model did show a significant in-group preference within the sample. This is in line with other studies using the same questions, in which the concrete question shows stronger effects with this age group (van Schaik & Hunnius, 2016). This finding indicates that the out-group modulation of the interference effect, although opposite to expectation, holds bearing.

Initially, more motor interference was expected to occur for in-group members than for out-group members. Since motor interference is an effect of action observation-execution coupling, and this, in turn, is thought to contribute to behavior copying, it was expected that the motor interference would reflect the general finding that we (unintentionally) copy individuals we like more than individuals we like less (Chartrand & Lakin, 2013; van Schaik & Hunnius, 2016). In favor of this underlying mechanism, a range of adult studies provide evidence for motor interference, under controlled circumstances, being a measure of action observation-execution coupling (e.g. Kilner et al., 2007) and for social modulations of mirror system activation (Molenberghs, 2013). However, in contrast to adult motor interference studies in which social factors are carefully controlled or discrete instances of mimicking an interaction partner's behavior, the present continuous-action measure was embedded in an explicitly instructed social context. As a result, an additional overlaying process involving task-related social motivations likely influenced the underlying mechanisms, and hence influenced the behavioral effects more strongly. For instance, the explicit emphasis on the social groups and the continuous nature of the movements might have led children to experience the task as an instance of coordination (Richardson, Campbell, & Schmidt, 2009); like other instances of coordination such as dancing together, participants were carrying out a similar, continuous behavior in the same space as the models. And since interpersonal coordination is a means of establishing liking and affiliation between individuals (Hove & Risen, 2009; Lakin, 2013), additional social goals might have complicated the

group manipulation's effect. Here, the out-group motor interference might have been caused by heightened attention towards the out-group model as a result of a need to overcome intergroup differences in what might be experienced as an affiliative, spatially coordinative task.

Two recent studies have found analogous results to those of the present study. In a motor interference study, adults saw pro-social words (e.g. 'group') or anti-social words (e.g. 'alone') superimposed on the screen displaying the model. Contrary to expectation, the anti-social word condition led to higher motor interference than the pro-social condition. One of the authors' interpretations of the findings holds that the anti-social condition threatened the "social harmony" of the interaction leading to increased attempts to affiliate with the model through increased coordination (Roberts et al., 2016, p.7). Likewise, in a study using novel groups, adult participants who performed a repetitive rhythmic interaction with an out-group member spontaneously synchronized more than those who interacted with an in-group member. The authors similarly interpreted these findings as an effect of overcoming the inter-group differences, paralleling findings of synchrony being used to increase affiliation (Miles, Lumsden, Richardson, & Macrae, 2011). In sum, the out-group interference effect observed in the present study might be a result of increased processing of the out-group member's movement stemming from a desire to overcome the differing group memberships.

Notably, though, variants of this account could lead to the same effects. Group boundaries can be perceived as competitive, even in the absence of explicit competition (Cikara & Van Bavel, 2014). Hence, the inter-group differences that in a cooperative case lead to increased affiliation attempts as discussed above (Miles et al., 2011), in another case might lead to wanting to appease a threat through affiliation (Rauchbauer et al., 2015), or in yet a third, more distinct case, could lead to enhanced monitoring of a competitor to facilitate prediction of their potentially dangerous behavior (Cikara & Van Bavel, 2014; Gutsell & Inzlicht, 2013). Each case, though, would lead to increased processing of out-group movements. With respect to this study, one could argue that because children were brought into close contact with a potential threat (i.e. an out-group member), the enhanced interference effect was a result of increased vigilance of the out-group's movement. However, this seems less likely for several related reasons. Threat effects in adults have primarily been found for existing groups and less so for novel group boundaries, which is likely caused by novel group manipulations leading to in-group preferences but not necessarily out-group derogation (Brewer, 1999; Cikara & Van Bavel, 2014). Also, explicit competition leads to considerably more intergroup hostility than simply dividing individuals into groups (Cikara & Van Bavel, 2014). Indeed, considering the

age of the current study's participants, these latter considerations are particularly relevant; novel-group-based out-group hate appears to develop between the ages of 6 and 8 (Buttelmann & Bohm, 2014), hence at a later age than the participants in the current study. Nonetheless, the out-group motor interference finding illustrates the complexity of social manipulations in combination with interpersonal tasks and indicates that this dynamic interplay of factors should be investigated further (Cikara & Van Bavel, 2014; Roberts et al., 2016).

Regarding the movement profile, only a limited effect on interference was found, and this was within the already-salient out-group condition. While past adult studies using a full-body paradigm have found higher interference in biological movement conditions (Kilner et al., 2007), a previous developmental study using a similar tablet-based design as the present study also found unexpected effects with respect to movement profile (Saby et al., 2011). Notably, in the tablet adaptation of the task used in this and past developmental studies, the similarity between the participants' and models' movements is reduced as compared to full-body paradigms. In the present stimuli (and in the past study's puppet stimuli reported in Saby et al., 2011, though the puppets are anatomically less similar than the present study's human models) the models make full shoulder-initiated arm movements that cross the midline as in the original adult paradigm but the participating children are asked to make unilateral movements with their wrists and hands in a precision pen-grip. As a result, the extent to which executing their action and observing the model's action elicit overlapping representations is limited, hence reducing the motor interference effect. Our attempt to make wrist and hand configuration more similar between participant and model by having the model hold a pen in her hand seems to have produced insufficient overlap. Additionally, the aforementioned social task demands which led to increased saliency of the out-group condition, possibly diminished attention towards less salient features of the videos (i.e. the kinematic differences) reducing the overall influence of the movement profile manipulation even more. Yet, since within the out-group condition the pattern tended towards biological trials leading to more interference than non-biological trials, the interference that was measured is also not merely a spatial congruency effect. Taken together, the degree to which the observed action and the executed action overlapped, and the saliency of the different characteristics of the stimulus (e.g. social group vs. movement profile) likely diminished the extent to which the movement profile manipulation affected children's motor interference.

In conclusion, this study investigated the sensitivity of children's motor interference to group membership and movement profile. Motor interference was only found for out-group members' movements. This effect likely stems from

heightened attention towards out-group members as a result of the coordinative nature of this explicitly instructed paradigm. Thus, this work demonstrates that the context of an interpersonal interaction uniquely interacts with the situation's social dynamics, and consequently this interplay affects underlying imitative processes. Future research should continue to investigate how social factors affect copying mechanisms during early childhood, as it is crucial in understanding inter-group interactions.



Mimicry of others' postures and behaviors forms an implicit yet indispensable component of social interactions. However, whereas numerous behavioral studies have investigated the occurrence of mimicry and its social sensitivity, the underlying neurocognitive mechanisms remain elusive. In this study, single pulse transcranial magnetic stimulation was used to measure corticospinal facilitation during a naturalistic behavior observation task adapted from the behavioral mimicry literature. Motor evoked potentials (MEPs) in participants' right hands were measured as they observed stimulus videos of a confederate describing photographs. MEPs were recorded while confederates were and were not carrying out hand and leg behaviors that also differed in spatial extent (i.e. large behaviors: face rubbing and leg crossing; small behaviors: finger tapping and foot bouncing). Importantly, the cover task instructions required participants to focus on the confederates' photograph descriptions in order to later perform a recognition test. A general arousal effect was found, with higher MEPs during stimulus video observation than during a fixation-cross baseline, regardless of whether or not the confederate was carrying out a behavior at the time of the pulse. Additionally, MEPs during observation of the larger two behaviors were significantly higher than the smaller two behaviors, irrespective of effector. Thus, by utilizing a controlled yet naturalistic paradigm, this study suggests that general sensorimotor arousal during social interactions could play a role in implicit behavioral mimicry.

Chapter 6

Measuring Mimicry: General Corticospinal Facilitation During Naturalistic Behavior Observation

J. E. van Schaik
L. M. Sacheli
H. Bekkering
I. Toni
S. M. Aglioti

(submitted).

During social interactions, individuals mimic their interaction partners' postures and otherwise-meaningless behaviors. Behavioral studies indicate that this phenomenon occurs largely outside of awareness yet is closely intertwined with the social dynamics of the interaction (Chartrand & Bargh, 1999; Chartrand & Lakin, 2013). The social sensitivity of mimicry suggests that it plays an important role in social interactions and deviations in the occurrence of mimicry might be indicative of social cognitive disorders such as autism spectrum disorders (Duffy & Chartrand, 2015; Wang & Hamilton, 2012). Thus, investigating the neurocognitive mechanisms of behavioral mimicry can contribute to our knowledge of implicit social processes relevant for daily interactions. However, only a handful of studies have started to address naturalistic behavioral mimicry from a neuroscientific vantage point (Hogeveen, Obhi, et al., 2015; Hogeveen, Chartrand, et al., 2015; van Ulzen et al., 2013).

The behavioral mimicry literature has advocated the "perception-behavior link" as the basic mechanism underlying the behavior (Chartrand & Bargh, 1999; Chartrand & van Baaren, 2009) and suggests that the phenomenon is underpinned by "mirroring" mechanisms (for a review see Rizzolatti & Sinigaglia, 2010). A myriad of human cognitive neuroscience studies have demonstrated that observation of another individual performing an action activates one's own motor system, a process referred to as sensorimotor simulation (Chong, Cunnington, Williams, Kanwisher, & Mattingley, 2008; Fadiga, Rizzolatti, Fogassi, & Pavesi, 1995; Kilner, Neal, Weiskopf, Friston, & Frith, 2009; Mukamel et al., 2010; for reviews see Caspers et al., 2010; Fox et al., 2016). Similarly, behavioral studies inspired by the "common coding approach" have shown that action perception and action execution are mutually interdependent (Prinz, 1997). For instance, in response compatibility paradigms (RCPs), interference in motor performance of movements occurs when concurrently-observed movements are incongruent to those being carried out (Brass et al., 2001, 2000; Kilner et al., 2003).

However, these studies were not designed to capture the implicit, communicative nature of behavioral mimicry. For instance, in RCP tasks, although referred to as a laboratory version of behavioral mimicry (Heyes, 2011), participants are prepared to perform the simple, pre-defined target actions that they simultaneously observe. This experimental approach is fundamentally different from the unpredictable and open-ended nature of mimicry. It might be argued that some neuroimaging studies alleviate this problem by using passive observation of actions. This is often the case in single-pulse transcranial magnetic stimulation (spTMS) measuring corticospinal facilitation. In such paradigms, an individual's primary motor cortex (M1) is stimulated with a magnetic pulse and motor evoked

potentials (MEPs) are recorded using electromyography (EMG) from the muscle controlled by that region of M1 (Fadiga et al., 2005, 1995). This method has provided evidence for time-locked, effector-specific sensorimotor simulation; MEPs are higher during passive observation of someone else performing an action with the same effector as the effector being targeted on the participant's M1 than during the observation of a static hand or a baseline (Alaerts, Swinnen, & Wenderoth, 2009; Borroni, Montagna, Cerri, & Baldissera, 2005; Gangitano, Mottaghy, & Pascual-Leone, 2001; Romani, Cesari, Urgesi, Facchini, & Aglioti, 2005; Strafella & Paus, 2000). Still, such studies use simple stimuli displaying single effectors and, importantly, lack an interactive context, limiting the translation of these findings to natural contexts.

In an attempt to start bridging this gap, van Ulzen and colleagues (2013) utilized an spTMS approach to measure sensorimotor simulation in a mimicry-like paradigm. Participants observed an actor performing clerical tasks whilst either touching his face or not, and spTMS pulses occurred during face touching in the face-touch condition and at moments the actor was not moving his hands in the no-face-touch condition. Higher MEPs were recorded in the face-touch videos than in the no-face-touch videos and baseline, providing the first evidence for the feasibility of using MEP techniques in combination with noisier, more naturalistic stimuli (van Ulzen et al., 2013). However, the stimulus videos entailed non-interactive observation, leading to two main limitations. First, contrary to what happens during social interactions, the task of remembering the order of clerical chores still required participants to focus on the actor's motor behavior rather than on communication with an interaction partner. Second, the stimuli themselves did not yet capture the dynamics of a typical social interaction including eye contact and information exchange.

The aim of the current study was to investigate whether a well-controlled MEP paradigm that reflects natural interactions and is amiable to a communicative cover task can be applied to investigate the role of sensorimotor simulation in behavioral mimicry. Building on the methodology used in previous spTMS studies on sensorimotor simulation, we wish to test whether behavioral mimicry leads to effector-specific increases in sensorimotor excitability during naturalistic action observation. To this end, we adapted a photograph description cover task commonly used in behavioral mimicry experiments (Lakin, 2013). Participants were informed that the study concerned the neural underpinnings of memory and communication between two individuals. In the stimulus videos, the confederates (thought to be past participants) described photographs to the participant while concurrently performing predefined behaviors typical of the mimicry literature. The participant's task was to listen to the descriptions to be able to subsequently

identify the photographs in a recognition task. spTMS was used to elicit MEPs of the participants' right index and little fingers while participants were viewing the confederates describe the photographs. Importantly, general sensorimotor arousal effects were assessed by applying spTMS both while the confederate performed a behavior and while the confederate sat still and described the picture. This provided an internally-valid baseline to discriminate between behavior-specific facilitation and general sensorimotor arousal (Labruna, Fernández-del-Olmo, & Ivry, 2011). Similarly, effector-specificity was investigated by exposing participants not just to the target hand behaviors (face rubbing and finger tapping), but also to the control leg behaviors (leg crossing and foot bouncing). Also, to allow for investigation of magnitude effects in the sensorimotor activation, behaviors of different spatial extents were used; for each effector, there was a behavior in which the effector covered a larger distance across the body (referred to as large behaviors; face rubbing and leg crossing) and one in which the effector only moved slightly (referred to as small behaviors; finger tapping and foot bouncing).

MATERIALS AND METHODS

Participants

Eighteen female participants between the ages of 20 and 33 were recruited for participation via a database of volunteers. Due to a technical problem, insufficient data was acquired for one participant. The final sample consisted of 17 female participants (Age: $M = 25.12$, $SD = 4.08$ years).

Only female participants were selected in order to avoid inadvertent gender-group effects that have been shown to influence mimicry (Lakin et al., 2008). Participants were screened for any contraindications for TMS and gave their written informed consent prior to participation. All but one participant were right-handed as confirmed by the Standard Handedness Inventory (Briggs & Nebes, 1975)⁶. Participants received monetary reimbursement and were debriefed as to the purpose of the experiment. The project was approved by the ethics committee of the Fondazione Santa Lucia and was carried out in accordance with the ethical standards of the 1964 Declaration of Helsinki.

⁶ The conclusions of the statistical analyses reported in the results section were unchanged when run without the left-handed participant.

Stimuli

Stimulus videos. Each stimulus video depicted the full body of one of two female models sitting on a chair (Figure 1). The models were professional actresses paid for their participation in stimulus recording. Two models were used in favor of one in order to minimize the influence of possible idiosyncrasies of a single model (as a control, likeability was assessed, see Procedure). In each stimulus video, the model described a photograph following a script as though they were spontaneously describing it. They carried out target behaviors according to a pre-defined timing scheme. While not carrying out any upper or lower limb behaviors, the model sat with her legs crossed, her right hand resting on the arm of the chair and her left hand not visible (Figure 1.a,b). The models freely moved their gaze, looking at the photograph (adjacent to the camera), the camera, and upwards as if in thought. On average, stimulus videos lasted 50.2 s ($SD = 2.28$).

The models carried out four types of behaviors in two effector categories, each with two types of behaviors; hand behaviors included face rubbing (Figure 1.c) and finger tapping (Figure 1.d)⁷, and leg behaviors included leg crossing (Figure 1.e) and foot bouncing (Figure 1.f). Per effector, one of the two behaviors was a large behavior as the models' effector covered more distance (i.e. face rubbing and leg crossing), and the other was more subtle, only moving a small distance between start and finish positions (i.e. finger tapping and foot bouncing). Behaviors lasted on average 3.00 s ($SD = 0.84$) per stimulus video, the model carried out four behaviors of one effector category. In other words, in each video, four repetitions of either only hand or only leg behaviors were shown, resulting in "hand videos" and "leg videos".

Participants observed 18 stimulus videos per model (i.e. nine hand and nine leg videos), hence 36 stimulus videos in total. Model identification was aided by framing the stimulus video on the left and right sides with yellow for one model and blue for the other, counterbalanced across participants (see Figure 1).

Stimulus photographs. The photographs described in the stimulus videos belonged to one of three categories: landscape, abstract sculptures, and houses. Landscape and house photographs were acquired from Wikimedia Commons and sculpture photographs were selected from the stimulus set of Era, Candidi, and Aglioti (2015). A pilot survey was performed to match stimulus photographs on the extent to which they elicited arousal and attention and how beautiful

⁷ Face rubbing included a full hand behavior while finger tapping entailed primarily the FDI. This distinction was included to allow for a further investigation of muscle-effector-specificity effects in the ADM and FDI, see Results section.

they were, as well as each photograph's resemblance to a matched distracter stimulus photograph (see below).



FIGURE 1 | Still frames from the stimulus videos. Model 1 (a) and 2 (b) while not performing target behaviors; face rub (c); finger tap (d); leg cross (e); and foot bounce (f). Note: arrows superimposed on still frames to illustrate movement direction. The white rectangle on the bottom left of each still frame indicates the placement of the photodiode.

EMG and TMS

EMG was measured with surface Ag-AgCl cup electrodes (1-cm-diameter) placed over the first dorsal interosseous (FDI) and abductor digiti minimi (ADM) of each participant's right hand using a belly-tendon montage, with the ground electrode on the ventral wrist. Two additional electrodes were placed on each participant's right leg, as if to measure EMG activity from the tibialis anterior muscle. The latter was done in order to not influence participants' covert attention to their own right hand over right leg. Accordingly, participants were briefly shown the online EMG signal of voluntary muscle contractions before stating the experimental session to ensure that they understood the procedure and necessity of remaining relaxed. EMG activity from the leg muscle was recorded but not further processed, as no MEP from the leg muscle can be expected by stimulation of the optimal scalp position for hand muscles.

Recordings were made using a CED Power 1401 (Cambridge Electronic Design Ltd., Cambridge, UK) connected to an Isolated Patient Amplifier System Model D360 (Digitimer Ltd., Hertfordshire, UK), and interfaced with CED Spike 2 software. The second-order Butterworth filter was set between 20 Hz and 2.5

kHz (1 kHz sampling rate). A 50 Hz notch filter was also applied. Signals were displayed at a gain of 1000.

Focal TMS was performed with a figure-eight stimulation coil (outer diameter of each wing 70 mm, Magstim polyurethane-coated coil), connected to a Magstim 200 Mono Pulse (Magstim Whitland, Dyfed, UK), over the left primary motor cortex. The optimal scalp position for eliciting MEPs in FDI was found by moving the coil in steps of 1 cm from the vertex while holding the coil tangential to the scalp with the handle pointing caudally and laterally at 45° from the midline. Individual resting motor threshold (rMT) was defined as the lowest stimulus intensity evoking five of ten MEPs with an amplitude of at least 50 μ V. Participants' rMT ranged between 43% and 63% of maximum stimulator output ($M = 53.41$, $SD = 7.43\%$). Stimulus intensity was kept at 20% above rMT during data collection ($M = 64.65$, $SD = 8.71\%$). EMG recording started 150 ms before TMS so as to be able to discard trials in which a muscular pre-activation (i.e. EMG signal exceeding 50 μ V) was detected.

During the experiment, TMS pulses were triggered by a photodiode placed on the bottom left of the screen that sent a transistor-transistor logic signal discharging the TMS. The photodiode was triggered when the screen underneath it turned black on the target frame of the stimulus videos (not visible to participants). MEP amplitudes were stored for offline analysis.

Procedure

At the start of the experimental sessions, participants were comfortably seated in front of a 17-inch monitor (1151 \times 964 pixels, refresh frequency of 60 Hz) at a distance of 60 cm with their right arm and right leg relaxed on supportive pillows. Participants were informed that the experiment would investigate the effects of TMS on memory and communication abilities. They were told that they had been selected to play the role of "receiver" and that they would be watching videos of two other participants previously selected to play the role of "senders". These senders (in actuality the stimulus video models) would be describing pictures and the participant's task would be to closely attend the videos in order to later identify the described pictures in a recognition test. In order to ensure that participants' would remain attentive throughout the experiment, they were informed that their own and the senders' reimbursements were dependent on their recognition performance. Participants were instructed to remain relaxed throughout the experiment and that the EMG measurement was used simply to ensure that they did not move as this could influence the effect of TMS during the task.

The experiment started and ended with a block of 18 fixation cross trials in which a fixation cross was presented at the center of the screen for 2 s. A TMS pulse was delivered between 1000 and 1600 ms from presentation of the fixation cross, with a random inter-trial interval ranging from 10 to 11 s.

Four experimental blocks were presented. Within each block, only one model's videos were presented: they consisted of four stimulus videos of one behavior category (e.g. hands) and five of the other (e.g. legs) in randomized order within the block. Block order was pseudo-randomized per participant such that the model in the video alternated between blocks. Stimulus presentation and randomization were controlled by E-Prime v2.1 software (Psychology Software Tools Inc., Pittsburgh, PA).

Per stimulus video, three MEPs were induced, two during a behavior (i.e. behavior pulses) and one while the model in the video was describing the picture but not carrying out a target behavior (i.e. catch pulses). This latter pulse was introduced to record corticospinal facilitation due to naturalistic observation independently from specific body movements. Since the models carried out four target behaviors per video and only two behaviors were pulsed, there were also two non-pulsed behaviors per video (i.e. catch behaviors). This ensured that participants would not form an association between the TMS pulses and the target behaviors as only half of the behaviors would be accompanied with a pulse. Behavior pulses were pseudo-randomized to occur 1, 1.5, or 2 s into the start of a behavior. Inter-pulse interval within the video was at least 10 s ($M = 18.12$, $SD = 7.40$ s) based on research that showed no change in corticospinal excitability with repetitive TMS at 0.1 Hz for 1 h (Chen et al., 1997). Similarly, behavior onset always occurred at least 5 s after the end of the previous behavior. Overall, 18 MEPs per pulse type were recorded per participant (i.e. 18 catch MEPs during hand videos, 18 catch MEPs during leg videos, 18 face rub MEPs, 18 finger tap MEPs, 18 leg cross MEPs, and 18 foot bounce MEPs).

At the end of each block, a recognition test was presented. Each of the described photographs from that block was shown paired with a distracter stimulus photograph for 5 s, after which participants were asked to indicate which of the two pictures had been described by the sender during the block. Stimulus photograph category was pseudo-randomized within and across stimulus video blocks; in doing so, each block contained three photographs of each of the three categories (i.e. landscape, sculptures, houses). After the recognition test of each block, participants were asked to rate how much the sender's descriptions helped them recognize the photographs, by using a visual analogue scale ranging from 'not at all' to 'very much so'. Finally, at the end of the experiment, participants

were asked to rate the two senders on five measures of liking (i.e. similarity, niceness, beauty, trustworthiness, likability) on the same visual analogue scale.

Following the experiment, a funneled debriefing questionnaire was administered (Chartrand & Bargh, 1999). Participants were first asked whether they believed the cover story. Next, participants were asked whether they believed that the actresses were indeed past participants. Then, participants were asked whether they had noticed the models' behaviors, and if so, which behaviors they noticed. At the end, the participants were debriefed as to the true aim of the experiment.

Data Handling and Analysis

Individual mean MEP amplitudes were calculated as peak-to-peak distance in mV, and averaged for each experimental condition. MEP amplitudes that fell 2.5 SDs above or below each participant's mean for that experimental condition, trials contaminated by muscular pre-activation, and MEPs lower than 0.05 mV were excluded. On average, 1.99% ($SD = 0.20$) of the total number of trials were excluded. Mean values of MEP amplitudes of both muscles during the pre-fixation did not differ from the post-fixation ($ps > 0.80$, 2-tailed paired-sample t-tests), thus ruling out the possibility of a general change in corticospinal facilitation during the course of the experiment.

First, mean experimental MEP amplitudes were normalized on (i.e. divided by) the individual's mean MEP amplitude of the fixation blocks and compared to 1 using one-sample t-tests. This comparison of "fixation-normalized" MEPs informs the extent to which there was a general heightening of corticospinal facilitation during naturalistic observation as compared to the fixation cross baseline.

Next, specific somatotopy of corticospinal facilitation during behavior observation was investigated. MEPs recorded in each video during the observation of a behavior were normalized on the MEP recorded during the catch pulse of that specific video. Thus, we could investigate the specific effects beyond the possible general arousal effects stemming from the observation of the naturalistic videos. This data preparation led to the inclusion of at least 9 and on average 14.82 ($SD = 0.83$) trials per behavior type, per muscle, per participant. The mean "catch-normalized" MEPs were entered into a repeated measures within-participants ANOVA with the factors muscle (ADM vs. FDI), effector (hand vs. leg) and behavior size (large vs. small). All tests of significance were based upon an a level of 0.05 and Bonferroni corrections were used where needed.

RESULTS

Fixation-normalized MEPs were higher than 1 in both muscles. More specifically, ADM MEPs showed significant corticospinal facilitation (all $p_{s_{corr}} < .027$). For the FDI, the finger tap MEPs showed a statistical trend towards significance ($p_{corr} = .06$), while all other MEPs also demonstrated significant general corticospinal facilitation as compared to fixation trials (all $p_{s_{corr}} < .001$).

The mean values of the catch-normalized MEP amplitudes are shown in Figure 2. In the RM ANOVA the only significant effect was the main effect of behavior size (all other $p_s > 0.120$). The larger behaviors (i.e. face rub and leg cross; $M = 1.28$) elicited significantly higher MEPs than the smaller behaviors (i.e. finger tap and foot bounce; $M = 1.16$; $F(1, 16) = 7.71$, $p = .013$, $\eta_p^2 = 0.325$). As there were no interactions, muscle-effector-specificity between the two types of behaviors and the two recorded muscles were not tested further.

Finally, the debriefing results were used to check for possible alternative explanations. Only two participants did not believe the cover story (i.e. that it concerned a memory experiment) but excluding them from the RM ANOVA did not affect the conclusions (main effect behavior size: $p = .035$, all other $p_s > .2$). Also, four participants did not believe that the models were past participants but excluding them from the RM ANOVA similarly did not change interpretation of the results (main effect behavior size: $p = .017$, all other $p_s > .2$). Participants' awareness of the behaviors reflected the main effect of behavior size (see Table 1). Whereas nearly all participants noticed the face rub and leg cross behaviors, only 7 noticed the finger tap and just 1 noticed the leg bounce.

Additional Task Measures

Performance on the photograph recognition task was near ceiling, with an average accuracy of 96.57% ($SD = 3.74$). Participants did not rate one model's descriptions as better than the other's ($p > .250$), nor did they prefer one model over the other on any of the liking measures at the end of the experiment ($p_s > .144$).

DISCUSSION

Whereas in other areas of social interaction research neuroscientific methods are used online during naturalistic behavioral paradigms (Kourtis et al., 2010; Meyer, Hunnius, van Elk, van Ede, & Bekkering, 2011; Sacheli, Aglioti, & Candidi, 2015; Sacheli, Candidi, Era, & Aglioti, 2015), this has rarely been

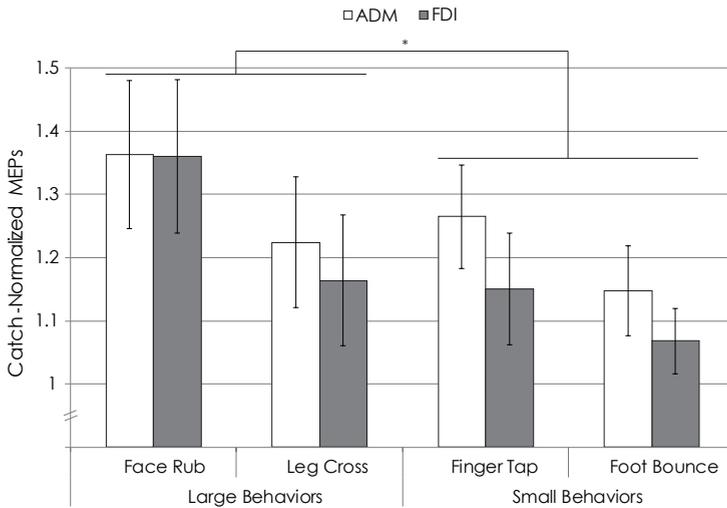


FIGURE 2 | Mean catch-normalized MEPs for each of the four observed behaviors for both the FDI and ADM muscles. Catch-normalized MEPs were calculated by dividing each behavioral MEP by the catch MEP of that video. Error bars indicate standard error of the mean. The asterisk indicates the significant main effect of behavior size.

TABLE 1 | Counts and percentages of participants who reported noticing each behavior during the debriefing.

	Face Rub	Finger Tap	Leg Cross	Foot Bounce
Noticed (n)	13	7	16	1
Percentage of Sample (%)	76	41	94	6

Note: sample size = 17.

realized in mimicry research (for exceptions see Hogeveen, Obhi, et al., 2015; van Ulzen et al., 2013). Instead, our understanding of the neural mechanisms of behavioral mimicry is limited to indirect translations from neuroimaging during observation of simple behaviors and RCPs. To start addressing this disparity between artificial paradigms and natural mimicry behavior, this study utilized spTMS to measure corticospinal facilitation while participants observed naturalistic stimuli as part of a cover task.

Comparisons of MEPs recorded while participants observed confederates only describing photographs and while the confederates were also performing behaviors allows us to disentangle the extent to which general and effector-

specific sensorimotor simulation is elicited during naturalistic action observation. If naturalistic behavior observation triggers non-time-locked general sensorimotor arousal, MEPs recorded during video observation (hence also including pulses occurring while the confederate was only describing the photographs without performing a target behavior) should be higher than during a fixation-cross baseline. Also, if natural sensorimotor simulation during a realistic communicative task is generally triggered by observed behaviors, higher MEPs for larger behaviors than smaller behaviors should be expected. Finally, if sensorimotor simulation is effector-specific as during passive action observation paradigms (Alaerts et al., 2009; Strafella & Paus, 2000; Urgesi, Candidi, Fabbro, Romani, & Aglioti, 2006; Urgesi, Moro, Candidi, & Aglioti, 2006), MEPs during observation of hand behaviors should be significantly higher than leg behaviors.

Demonstrating a general sensorimotor arousal effect, MEPs were higher during video observation than during a fixation-cross baseline, regardless of whether or not the confederate was performing a behavior or which behavior it was. Even when correcting data for this general arousal effect, corticospinal facilitation was higher for the larger behaviors, face rubbing and leg crossing, than the smaller behaviors, finger tapping and foot bouncing. This was the case for both recorded muscles and for both hand and leg behaviors.

This finding of general sensorimotor arousal occurring during naturalistic observation of another individual is in line with past MEP studies. Van Ulzen and colleagues (2013) did not find significant differences in MEPs from the face-touch condition and those measured during observation of a static image of the seated confederate, suggesting that the motor cortex is already generally active when observing an individual (in a static image or in a video). Correspondingly, Hogeveen and Obhi (2012) found that following a social interaction, participants' MEPs while observing human actions were significantly higher than for robotic actions, while this was not the case for participants who had not first engaged in a social interaction. Together, these MEP findings indicate that sensorimotor simulation during naturalistic observation of others is generally heightened and that this general enhancement extends beyond the duration of a single observed action.

Furthermore, in the present study, the general corticospinal facilitation effect was enhanced for the more-noticed behaviors as seen in a statistically large effect of behavior size ($\eta_p^2 = 0.325$). In other words, beyond the general arousal effect of observing another individual, observing that individual performing a behavior caused additional sensorimotor arousal. This suggests that during a natural interaction in which mimicry typically occurs, observing a behavior will increase general sensorimotor arousal, perhaps to the extent that a behavior

would actually be executed. In line with this more general sensorimotor simulation mechanism, behavioral mimicry experiment methodologies are not always specific regarding the precise behavior execution nor the timing thereof (van Ulzen et al., 2013). Repetitive behaviors, such as face touching, are used widely in behavioral mimicry studies and are often demonstrated regularly throughout the interaction by the confederate (Lakin, 2013). The description of how these face touch behaviors are coded is often limited, such that it could be interpreted by the reader to be considered mimicry if an individual *rubs* his chin several *seconds* after seeing an interaction partner *scratch* her forehead. Thus, the subjective experience of mimicry and related social consequences (Chartrand & Lakin, 2013), might not require a one-to-one matching of effectors, muscles and timing. Interestingly, the results from this study indeed reflect this more general type of sensorimotor simulation.

While this study provides evidence for general sensorimotor arousal occurring during naturalistic observation of others, no clear effects of effector-specificity were found. In interpreting this finding, it is important to consider that the corticospinal facilitation measured here was elicited in a different context than the MEPs of past studies. Typical MEP studies ensure participants' full visual attention by presenting simplistic single-effector actions, and can hence carefully manipulate action-pulse timing (Fadiga et al., 2005). Such paradigms have shown that corticospinal facilitation during action observation anticipates the time-course of action kinematics (Urgesi et al., 2010) and is influenced by whether the observed action is successful (Aglioti, Cesari, Romani, & Urgesi, 2008; Candidi, Sacheli, Mega, & Aglioti, 2014). Importantly, these findings highlight characteristics of sensorimotor simulation that can be crucial in other social contexts, such as when coordinating with a partner during joint action (Bekkering et al., 2009; Knoblich & Jordan, 2003; Sacheli, Candidi, Pavone, Tidoni, & Aglioti, 2012; Sacheli, Tidoni, Pavone, Aglioti, & Candidi, 2013; Vesper, Butterfill, Knoblich, & Sebanz, 2010; Vesper, van der Wel, Knoblich, & Sebanz, 2013). On the contrary, in our "social" context we find evidence in favor of an unspecific, general facilitation that is independent from the specific motor behavior carried out by the participant. Crucially, the confederates' motor behavior was irrelevant for the participants' task, as is the case in real-life communicative situations where mimicry usually occurs. Taken together, the relevance of the observed behaviors and the need for fast predictions to ensure appropriate interactive responses likely dictate the level of sensorimotor simulation.

Moreover, it can also be the case that both the specific and more general functions of sensorimotor simulation might be interlinked and concurrently occur in interactive situations. For example, this is evident when participants need to

precisely synchronize with a partner but still show a socially-induced modulation of involuntary simulation of their movements (Sacheli, Christensen, et al., 2015). Indeed, the terms perception-behavior link or sensorimotor simulation have been used to refer to the mechanisms of a range of behaviors and processes and likely indicate activity of a shared neural substrate. Importantly, however, only through context-specific investigations does it become clear which sub-mechanisms are involved and to which extent.

The notion of context-specific investigations has proved insightful in other areas of sensorimotor simulation research. For example, neuroimaging studies have long since identified differences in simply observing an action versus observing an action to subsequently imitate it (Grezes, Costes, & Decety, 1998; Schuch, Bayliss, Klein, & Tipper, 2010; Suchan, Melde, Herzog, Hömberg, & Seitz, 2008). The notion of context-specificity therefore emphasizes that using substitute tasks like RCPs to infer possible mechanisms of another behavior, like mimicry, should be exercised with caution. Indeed, this distinction was recently demonstrated in a transcranial direct current stimulation study. The roles of two regions thought to influence sensorimotor simulation, the inferior frontal cortex and the temporal-parietal junction, were dissociated, demonstrating that each had a distinct effect on producing behavioral mimicry and performance on a RCP (Hogeveen, Obhi, et al., 2015).

Overall these observations and our results highlight the caveats of using non-naturalistic set-ups as a proxy for natural social behaviors. This might also hold when social modulations of behavioral mimicry are taken into account. Many of the social factors found to influence behavioral mimicry also affect performance in RCPs (Hogeveen & Obhi, 2013; Leighton et al., 2010; Wang et al., 2011). Correspondingly, corticospinal facilitation can be also influenced by social factors, such as social groups (Déry & Théoret, 2007; Molnar-Szakacs et al., 2007) and social power (Hogeveen, Inzlicht, & Obhi, 2014). However, just like the features of corticospinal facilitation might change depending on the context, RCPs and spTMS results are perhaps not sensitive to all of the same social factors as mimicry (see for instance Farmer, Carr, Svartdal, Winkielman, & Hamilton, 2016). Thus, future behavioral mimicry research should take further steps to closely match experimental context with the ecological context of interest.

Although the general sensorimotor arousal effects found in this study can go a long way in explaining the breadth of temporally spaced effects found in the behavioral mimicry literature, some level of anatomical specificity would nevertheless be required for mimicry to be experienced as such. Subjectively, it would not be perceived as mimicry if one individual crossed their legs after they observed their interaction partner rub their face. However, such evidence for

somatotopic mapping between observed behaviors and corticospinal facilitation was not clear in this study. One limitation of the cover task and naturalistic stimuli is that participants were free to look anywhere, likely leading them to primarily fixate on the face. Indeed, only 41% of the participants reported noticing the finger tap at all during the experiment and just a single participant noticed the leg bounce. Moreover, for those participants who did notice, the likely fewer trials in which the behavior was observed was averaged with the likely more numerous trials that the behavior was not being observed at the time of the TMS pulse. This matter could be investigated in future simultaneous TMS and eye-tracking studies utilizing such naturalistic stimuli. It would then be expected that particularly when the behaviors were fixated on, the enhancement of sensorimotor arousal would be highest. Nonetheless, the pattern of results found in this study provide a starting ground for further investigations into the role of sensorimotor simulation in producing behavioral mimicry.

In conclusion, this study employed a naturalistic spTMS paradigm to measure the nature of online sensorimotor simulation that could play a role in producing behavioral mimicry. General arousal effects were found, as observing the stimulus videos elicited increased corticospinal facilitation as compared to a fixation-cross baseline. Additionally, the size of observed behaviors affected MEP amplitudes. Taken together, this study provides support for general sensorimotor simulation being involved in producing behavioral mimicry and opens the door for novel perspectives on sensorimotor simulation in naturalistic interactions.

Chapter 7

General Discussion

In this thesis, I set out to investigate the emergence of social behavioral mimicry during early childhood and the developmental and neurocognitive mechanisms underlying it. In doing so, I first identified mimicry in 3- to 6-year-olds' behavior and found that it was socially modulated by approximately 5 years of age (*Chapters 2 and 3*). This developmental trajectory was used to inform an investigation into the developmental mechanisms of social behavioral mimicry; 5-year-olds' social understanding was related to their overall mimicry while the social selectivity of children's mimicry could be predicted from individual differences in inhibitory control (*Chapter 4*). Additionally, young children's perception-behavior mapping was found to be sensitive to the social identity of their interaction partners (*Chapter 5*) and an adult TMS study provided further evidence for a socially-sensitive role of the mirror system in behavioral mimicry (*Chapter 6*). Below, I first examine how these findings contribute to our understanding of behavioral mimicry. Subsequently, I evaluate the limitations of behavioral mimicry methodology. Finally, I explore the implications of these experiments within a wider body of social interaction literatures.

DEVELOPMENT AND MECHANISMS OF MIMICRY

As reviewed in *Chapter 1*, behavioral mimicry has been the subject of extensive behavioral research in adults. However, where this behavior comes from has remained unanswered. It was unknown whether young children mimic and whether their mimicry is sensitive to the social dynamics of an interaction, as is the case for adults' mimicry. Similarly, while the perception-behavior link has been the advocated neurocognitive basis of mimicry (Chartrand & Bargh, 1999; Chartrand & van Baaren, 2009), there was only limited evidence for its role in naturalistic interactions conducive to behavioral mimicry (Hogeveen, Chartrand, et al., 2015).

Findings from both developmental and neurocognitive research into copying behaviors provided the theoretical framework in which the present investigations were grounded. Since infants start to imitate actions by the end of their first year of life (Jones, 2007) and toddlers use imitation to initiate social interactions (Eckerman & Peterman, 2004), it was expected that children would be capable of mimicry at least by the end of toddlerhood. Furthermore, the increasing social sensitivity of young children's behavior during experimental imitation paradigms (e.g. Yu & Kushnir, 2014) suggested that social-cognitive development would likely influence social behavioral mimicry during the kindergarten years. Based on evidence for the perception-behavior link's sensitivity to the social

characteristics of explicit action tasks in adults (e.g. Gutsell & Inzlicht, 2010; Molenberghs et al., 2013) and possibly also in young children (Marshall et al., 2010), it was expected that this neurocognitive mechanism would also underlie implicit behavioral mimicry. Overall, the findings from the present studies largely matched these predictions.

Developmental Trajectory

Chapter 2 demonstrated that 3-year-olds mimic and this finding was replicated in *Chapter 3*. At this age, the basic mechanism necessary for mimicry behavior is present, as the mirror system likely develops during infancy and toddlerhood (Cook, Bird, Catmur, Press, & Heyes, 2014; Cuevas, Cannon, Yoo, & Fox, 2014; Del Giudice et al., 2009; Ferrari et al., 2013). Toddlers are also experienced imitators (Jones, 2009) and imitate peers during play (Eckerman et al., 1989). Interestingly, past studies have found that peer imitation decreases in prevalence across early childhood starting at the age of 3, which was suggested to be due to the development of other pathways of affiliation (Abramovitch & Grusec, 1978; Lubin & Field, 1981; Nadel, 2002). Hence, the present findings suggest that at the age at which explicit instances of peer imitation start to diminish, a more implicit form of behavior copying is already emerging. Yet, whether behavioral mimicry is present in young children's peer interactions remains unknown. An essential next step in ascertaining mimicry as a social interaction behavior during development is for future studies to investigate its emergence in peer interactions. The present mimicry findings serve as a guide, since they for the first time indicate that young children, at times, can display behavioral mimicry.

Although the social manipulations of *Chapters 2 and 3* did not affect 3-year-olds' mimicry, *Chapter 3* found that 4- to 6-year-olds' behavioral mimicry was sensitive to the social identity of their interaction partners. Following allocation to a novel group, the kindergartners mimicked their in-group members more than out-group members. These findings suggest that, as in adults (Lakin et al., 2008), mimicry during childhood can already convey an affiliative message, "I (am) like you". The sensitivity of children's behavior to group manipulations has previously been documented in instructed imitation paradigms (Oostenbroek & Over, 2015; Watson-Jones et al., 2016) and in preference tasks (Dunham et al., 2011; Richter et al., 2016). The present study adds to these findings by demonstrating that uninstructed forms of interaction behaviors are similarly guided by group boundaries. As such, this study contributes to theories of the importance of groups for guiding and fostering affiliative social interactions (e.g. Haun & Over, 2015; Heyes, 2013).

Chapter 3's evidence that the young children mimicked in-group members more, inversely indicates that they mimicked out-group members less. Decreased or even negative mimicry of out-group members has been previously documented in adult research (Yabar et al., 2006). In *Chapter 3* it was put forth that this ability to regulate who gets mimicked could be a product of children's developing behavioral control. This was supported by the results of *Chapter 4*; although the social manipulation of this study did not affect children's mimicry on a group level, individual differences in performance on an inhibitory control task were predictive of the extent to which they mimicked the sticker keeper more than the sticker sharer. In line with increasing behavioral control during early childhood (Carlson, 2005), and the social sensitivity of older but not younger children's mimicry in *Chapter 3*, it seems that behavioral control might be one of the developmental mechanisms contributing to the social sensitivity of mimicry.

Furthermore, *Chapter 4* also explored the relation between behavioral mimicry and social development. Children's total mimicry scores were positively correlated with a measure of their social understanding. Since the utilized Children's Social Understanding Scale broadly measures children's understanding of others in their daily lives (Tahiroglu et al., 2014), there could be several pathways through which social understanding and mimicry are related. Following adult findings (Chartrand & van Baaren, 2009), perspective taking and mimicry might be related through an enhanced attention for other individuals (Chartrand & Bargh, 1999). It could also be the case that an understanding of social relationships and affiliation (e.g. Plötner et al., 2016) is related to performing affiliative behaviors oneself. Additionally, a child's sensitivity to social relationships based on the extent of her own desire for relationships, for example as governed by her attachment style, might drive the expression of affiliative behaviors. Particularly the latter pathway might be utilized in future research as a more sensitive factor that could influence toddlers' or young children's social mimicry. Indeed, attachment style has been found to affect adult's mimicry levels (Hall, Millings, & Bouças, 2012). Thus, although 3-year-olds were the youngest children studied in this thesis and sensitivity to the social manipulations was only found in 4- to 6-year-olds, individual differences in social understanding might reveal mimicry in some children earlier on in development.

Taken together, these studies provide a first glimpse into the development of behavioral mimicry and suggest separable roles of two developmental mechanisms, behavior control and social understanding. Further research is needed to address the questions raised by this initial investigation, such as whether young children already display behavioral mimicry in natural peer interactions and how different aspects of children's social and cognitive development are related

to the emergence of social mimicry. Through continuing this exploration into the early development of behavioral mimicry, we might come to find that, akin to how imitation contributes to children's social cognition (Meltzoff & Williamson, 2010), mimicry might likewise play a valuable and dynamic role in children's social development.

Neurocognitive Basis

Chapter 6 provided insight into how mirror system⁸ activity might lead to behavioral mimicry during natural social interactions. In this TMS study, observing an interaction partner, even when not performing specific behaviors, resulted in significantly higher MEPs than those elicited during a nonsocial baseline. Beyond this general enhancement effect, MEPs recorded during noticed behaviors were significantly higher than during less noticed behaviors. Together, these findings suggest that observation of an interaction partner generally enhances sensorimotor activation, hence providing an already higher level of motor activity (see also Hogeveen, Chartrand, et al., 2015; Hogeveen & Obhi, 2012). Consequently, when the interaction partner does perform a behavior, the sensorimotor cortex is even more active, and this could potentially surpass the threshold of activity required for overt motor movements (granted other neurocognitive mechanisms allow). More simply, while we evidently do not copy everyone around us at all times, this generally enhanced mirror activity during an engaging social interaction suggests that when an interaction partner's behavior is observed it could more easily result in behavioral mimicry.

In addition to a general enhancement effect caused by observing another individual regardless of whether they are performing behaviors (i.e. passive nonsocial observation versus passive social observation; *Chapter 6*), past adult neuroimaging studies have indicated that specific social characteristics, such as group membership (i.e. in-group members' hand actions versus out-group member's hand actions; Gutsell & Inzlicht, 2013; Molenberghs et al., 2013), modulate mirror system activity during action observation. Since adults' behavioral mimicry displays similar sensitivities (Lakin et al., 2008; Yabar et al., 2006), it could be that this specific social mirroring further stimulates the overt production of behavioral mimicry. If this is the case, then this should also already be evident in young children at the point at which they socially mimic. Though not a direct measure, the motor interference paradigm used in *Chapter 5* provided a feasible, child-friendly means of investigating the possible social sensitivity of

8 As in *Chapter 1*, 'mirror system' terminology is reserved for discussing the neural implementation of the 'perception-behavior link', which, conforming to the behavioral mimicry literature, is used to describe behavioral findings or the general phenomenon.

children's perception-behavior mapping. The interference in 4- to 6-year-olds' movements, caused by simultaneously observing an incongruent motion path to the one being performed, was higher when the children observed an out-group member than an in-group member. Hence, it seems as if already during early childhood, specific social effects could influence the degree of mirroring activity.

Together, *Chapters 5 and 6* suggest that overt behavioral mimicry could be the product of a mirror system that is generally engaged during social interactions and is possibly further enhanced by the specific social relevance of one's interaction partner. Taking this as the basis of behavioral mimicry, the mimicry findings from *Chapter 4* would suggest that, at least in children, these social modulation effects might be regulated by behavioral control mechanisms. In this study, inhibitory control, measured through a cognitive task, predicted the extent to which children's mimicry was socially selective. Importantly, though, these findings do not necessarily implicate an active, direct inhibition of the motor activation resulting from perception-behavior mapping (though this might occur at times, such as when you suddenly notice you are about to mimic your interaction partner or during a TMS study investigating mimicry in which you are required to sit still; see Wang & Hamilton, 2012). Instead, these effects might be the result of a neurocognitive network involved in upregulating perception-behavior mapping (Heyes, 2011). Further neurocognitive research is needed to distinguish between such pathways.

In sum, these studies can serve as a starting ground for future investigations into the interplay of neurocognitive processes underlying mimicry. Central to understanding the neurocognitive mechanisms of mimicry is studying how mirror system activity can lead to overt behavioral mimicry and at which point during the processing of observed behaviors social modulatory effects operate. An exciting avenue for addressing such questions is through ongoing advances in neuroimaging. What has greatly hampered our understanding of neurocognitive mechanisms of mimicry is the challenge of incorporating a natural, implicit, social behavior into a restrictive neuroimaging setup. Recent technological and methodological advances have increased the applicability of noninvasive stimulation techniques in cognitive neuroscience (Sandrini, Umiltà, & Rusconi, 2011). Particularly of interest are repetitive TMS and transcranial direct current stimulation techniques, which can be used to enhance or inhibit specific regions of the cortex and ensure that, following stimulation, the participant is free from any constraining apparatuses (Dayan, Censor, Buch, Sandrini, & Cohen, 2013; but see also Horvath, Forte, & Carter, 2015). Such techniques could be used to provide causal evidence for the involvement of specific neural correlates, and

thereby the underlying processes, during naturalistic, live, social interactions (e.g. Hogeveen, Obhi, et al., 2015).

OPERATIONALIZING BEHAVIORAL MIMICRY

Following Chartrand and Bargh's (1999) seminal paper, behavioral mimicry experiments have largely adhered to a particular formula. These adult paradigms have also provided the basic template for the mimicry experiments presented in this thesis. Yet, capturing a dynamic social behavior in a controlled laboratory setup inevitably presents an array of challenges. The adaptation of adult mimicry paradigms to child-friendly designs has brought to light several methodological limitations in the mimicry literature and pinpoints facets of measuring mimicry that necessitate further investigation.

Baselines

With a few exceptions (e.g. Emanuel, 2012), baselines have only intermittently been utilized in experimental designs and have largely been ignored on a theoretical level. It is for this reason that in the overview of adult work in *Chapter 1*, the type or absence of baselines was noted per experiment. Indeed, as described by Lakin (2013, p.543) with respect to typical mimicry experiments, “[h]ow much *mimicry* occurs is *sometimes* [emphasis added] compared to a baseline situation to control for participants’ initial tendencies to engage in the behavior in question.” However, I would argue that mimicry cannot be directly measured during a single experimental session; instead, whether participants mimic or not is established through a comparison of behavior rates during a baseline period (or of a control group) and an experimental period (or group).

In an ongoing attempt to improve how we measured mimicry, the baselines progressed together with the experimental paradigms in this thesis. In *Chapters 2 and 3*, the baselines were designed as in the majority of earlier adult studies (e.g. Chartrand & Bargh, 1999; Cheng & Chartrand, 2003; Lakin et al., 2008); the participants were recorded for a brief nonsocial period of time preceding the experimental session. In these chapters, the priority was to maintain children’s visual attention towards the screen so as to best match the experimental period’s setting. While in *Chapter 2* the 3-year-olds’ task was to watch a short (~1 min) animation clip, in *Chapter 3* a simple game was used as the baseline so that it could be longer (i.e. 2 min) while still ensuring also older children’s visual attention. In these studies the baseline matched the video-based stimulus presentation, as participants never interacted with the models in the stimulus videos. Addition-

ally, the use of this conventional, nonsocial, baseline design (e.g. Lakin et al., 2008) allowed for a higher procedural overlap with adult findings; as a result, one could argue that the mimicry identified in these studies closely resembles the effects found in adult studies.

However, arousal due to the social nature of interactions could generally affect behavior rates, thereby creating a difference between a nonsocial baseline and the experimental period by definition (van Swol & Drury, 2006; Yabar et al., 2006). Hence, in a pilot study preceding the experiment presented in *Chapter 4*, the first few minutes of a story session in which the model did not yet perform any behaviors were used as a baseline (van Schaik, Peereboom, & Hunnius, 2014). But, it could further be the case that behavior rates change throughout an interaction, which in any baseline-then-manipulation design means that temporal influences on behavior rates are confounded with the resulting measure of mimicry. Temporal effects of mimicry were documented by Charny (1966) in his analysis of a videotaped interaction, as he found that postural congruence increased during the course of the conversation. Consequently, in *Chapter 4* a control group of participants who were not exposed to the target behaviors was used to ascertain mimicry in the experimental group, instead of using a preceding baseline. This between-participants design resembles those of adult studies that investigate the consequences of being or not being mimicked (Lakin, 2013).

Arguably though, a between-participants design has other limits. Indeed, on a group level, only negative mimicry was identified in *Chapter 4* and it cannot be ruled out that these effects were at least partially due to the baseline methodology. For example, without within-participant comparisons, individual differences in typical behavior rates cannot be entirely factored out. Additionally, this design required the experimental group to observe the storytellers regularly perform behaviors, whereas during the control group's stories, the storytellers were much more limited in their movement. This less dynamic storytelling situation might have created a less natural interaction context, possibly increasing the control group children's fidgeting as a result.

On the whole, while the presented experiments reflect the diverse baselines used in adult mimicry studies, they likewise point to a widespread shortcoming of mimicry methodology. Further research should determine how the baseline measure influences mimicry quantification and thereby define best practices in defining behavioral mimicry. As a start, it should be tested whether the different types of baseline settings (e.g. one minute nonsocial, first minute of interaction, full interaction, etc.) lead to different behavior rates (corrected for duration), as this would indicate the extent to which baseline styles can bias mimicry calculations.

Behavior Differences

While considered to be a general phenomenon, evidence for behavioral mimicry comes primarily from the early explorations of postural congruence (e.g. LaFrance, 1979) and experimental investigations of face rubbing and foot bouncing (Emanuel, 2012). A few authors have strived to show the generalizability of social effects by using face rubbing in one experiment and foot bouncing in the next (e.g. Lakin & Chartrand, 2003), or by using one of these classic behaviors alongside pen playing (e.g. van Baaren et al., 2003) or arm touching (e.g. van Swol & Drury, 2006). In line with this attempt to test the generalizability of mimicry, the experimental designs presented in this thesis used multiple target behaviors. Particularly *Chapter 2* investigated differences between behavior types and found that, of the behaviors and facial expressions mimicked (i.e. cheek scratching, mouth rubbing, yawning, head wiggling, and frowning), there were no significant differences in rates. This suggests that behavioral mimicry in young children is to a certain extent wide-ranging and not bound to the copying of a particular behavior. Based on this finding, in *Chapters 3* and *4* behavior types were counterbalanced across the within-participants social manipulations.

Chapter 4's between-participants baseline exemplified another important reason to use multiple behaviors. In the control group, there was a significant difference between face rubbing and hand rubbing, suggesting that this age group might typically perform the latter more often in such a context. In contrast, adult participants in *Chapter 6* reported noticing face rubbing more than a hand behavior and in another adult study, face rubbing was performed more often by the adult participants than leg behaviors (Emanuel, 2012). These findings suggest that typical child and adult behaviors might differ. Conceivably, there might be a developmental shift towards face-oriented behaviors, as these resemble personal grooming behaviors. In addition to age-related differences, individual differences also exist. For example, Lakin and colleagues (2008) reported significant main effects of baseline covariates with medium to large effect sizes, indicating noteworthy individual differences in natural behavior tendencies. With respect to both individual and age-related differences, it is imperative to consider whether these could disproportionately affect mimicry due to biases in the underlying mechanisms. Perhaps we tend to mimic the behaviors we spontaneously perform ourselves. A possible reason for this could be that there might be stronger perception-behavior associations for commonly performed and observed (i.e. trained) behaviors (Catmur, Walsh, & Heyes, 2009; Heyes, 2010). Indeed, infants tend to start imitating behaviors only after they have extensively practiced them themselves (Jones, 2006b). In future mimicry experiments, testing

for behavior differences could maximize the sensitivity of mimicry paradigms and potentially shed some light on the mechanisms of mimicry.

Behavior Types

Defining behavior types has also received limited direct attention. Oftentimes, what the confederate demonstrates and which participant behaviors are counted are not explicitly stated in mimicry papers. For instance, in a footnote of Chartrand and Bargh (1999) the reader discovers that face rubbing can include “many physical gestures that can be made in the facial area (e.g., scratching an itch, playing with an earring, fixing hair)”, yet what is included in their precise coding scheme is not listed (Chartrand & Bargh, 1999). An example of an exception to this scarcity of behavior definitions is Hall and colleagues (2012) who describe the modeled face rubbing as variable, including “all elements of the face, (e.g., cheek, temple, forehead, eye-brow, nose, below nose, mouth, chin and jaw line) with each area being touched at least twice and some touches covering multiple areas.” (Hall et al., 2012). As opposed to the distinct face behaviors (i.e. cheek scratching and face rubbing) of *Chapters 2 and 3* (see also Emanuel, 2012), *Chapter 4* followed this clustering of face touching behaviors. Support for such a broader classification comes from a controlled experiment comparing the effect of effector (hand or foot) and movement (inward-outward or forward-backward) on liking. Adult participants liked the video models more if they moved with the same effector as the participant did, but movement similarity did not affect liking (Sparenberg, Topolinski, Springer, & Prinz, 2012). Thus, it seems that precise movement matching is not a requirement for mimicry’s social benefits, but this raises several questions. At which point is a behavior no longer mimicry? And how does a perception-behavior matching system, known to be capable of precise mirroring (Fadiga et al., 2005), also generate this imprecise behavioral mimicry? Again, further investigations will be needed to address such questions in our pursuit of the mechanisms of behavioral mimicry.

BEHAVIORAL MIMICRY AS A PART OF DYNAMIC SOCIAL INTERACTIONS

Placed in the context of a wider body of literature, the experiments presented in this thesis highlight the importance of considering the dynamicity of interactions and reveal mimicry to be one component of a complex behavioral repertoire.

Social Dynamics

The reported studies had mixed effects with respect to the intended social manipulations. While in *Chapter 3* 4- to 6-year-olds mimicked in-group members more than out-group members, the motor interference of *Chapter 5's* 4- to 6-year-olds was more affected by out-group members' movements. Also, on a group level, the 5-year-olds of *Chapter 4* did not significantly differentiate between a sticker sharer and a sticker keeper in their negative mimicry of these models, though descriptively this group tended to mimic keepers more. Similarly, social effects contrary to expectations have been documented in a handful of other adult social interaction studies (e.g. Miles et al., 2011; Roberts et al., 2016), and perhaps in many more unpublished studies. Though seemingly contradictory, these effects instead exemplify the importance of considering the dynamics of each experimental interaction.

Depending on the context, the social dynamics of an interaction can differentially determine affiliation goals. Whereas a general liking-based preference might lead to higher affiliation goals in typical interactions (e.g. *Chapter 3*; Lakin & Chartrand, 2003), certain situations, such as being ostracized from a communal game (Lakin et al., 2008; Watson-Jones et al., 2016) or knowing you will later meet or collaborate with an individual (LaFrance, 1985), could increase the need to affiliate with disliked or out-group individuals (Miles et al., 2011). Following the general neurocognitive mechanisms outlined above, the heightened social relevance of this individual would be evident in enhanced perception-behavior mapping (e.g. *Chapter 5*) which, in turn, could lead to relatively more mimicry of this individual (e.g. *Chapter 4*). Hence, in interpreting past work and designing future studies, it is imperative to consider how the social dynamics and contextual demands interact to affect the underlying social motivations during interactions.

Behavior Dynamics

As a product of the social dynamics and tasks of an interaction, the presence of copying behaviors is also variable. Though ostensibly following similar methodological formulas, adult experimental mimicry rates vary from negative mimicry (e.g. Yabar et al., 2006) and the absence of mimicry effects (e.g. van Swol & Drury, 2006) to low prevalence (e.g. Cheng & Chartrand, 2003) and even fairly frequent mimicry (e.g. van Baaren et al., 2003). Similarly, the present studies found low to average levels of mimicry (*Chapters 2 and 3*) but also negative mimicry (*Chapter 4*). In addition to an unknown number of unpublished null results (including an adult pilot study preceding the experiment of *Chapter 6*),

this range of findings raises the question, when do experiments elicit mimicry and when do they not?

In addition to the methodological considerations discussed previously, an answer to this question could lie in the context of the experimental interactions. In mimicry experiments, the goal is to isolate behavioral mimicry, and since it is a communicative behavior, this necessitates limiting other communication routes to enhance the use of mimicry. It could be for this reason that the majority of published mimicry studies utilize structured verbal interactions with a confederate (Emanuel, 2012), such as scripted interviews (Lakin & Chartrand, 2003) and the photograph description task (Chartrand & Bargh, 1999). For example, during the photograph description task, the experimenter often remains in the corner of the room while the confederate and participant describe the pictures to one another (Hall et al., 2012; van Baaren et al., 2003), essentially obliging the participant to refrain from verbal routes of affiliation as these would deviate from the instructed task. Moreover, in the original study, confederates were instructed to limit eye-contact (Chartrand & Bargh, 1999), which might have limited nonverbal communication through facial expressions as well. Hence, perhaps through restricting verbal and nonverbal social signals, the need for participants to use mimicry to affiliate in these contexts is amplified.

In other words, since different forms of behavior can communicate affiliation, the contextual dynamics likely define which behaviors are expressed. For instance, whereas during a face-to-face conversation mimicry might be the least-obstructed route, when operating a novel apparatus together over-imitation might be a more effective means of communicating affiliation. Consequently, studies in which communication routes are not as limited might find lower mimicry prevalence. This might have been the case in *Chapter 4*, in which children already had a chance to freely interact and affiliate with experimenters prior to the video-based story session, thus reducing the need to mimic in this now less-affiliative video setting. Yet, limiting communication routes entirely by solely presenting models in videos has arguably also led to low mimicry rates (*Chapters 2 and 3*; Lakin & Chartrand, 2003; van Baaren et al., 2004; Yabar et al., 2006). Support for this 'limitation of affiliation routes' explanation of interaction behavior prevalence comes from an over-imitation study with elementary school children. In this study, 6.5- to 8-year-olds over-imitated most when the demonstration was live as compared to televised (i.e. affiliation was possible) and the model did not make eye contact (i.e. other communication paths were limited; Marsh et al., 2014).

Taken together, since mimicry is one means of communicating affiliation, it should be considered as part of a wider system of affiliation behaviors whose

individual occurrences are a dynamic product of the interaction. Instead of dampening interest in behavioral mimicry, though, this understanding should inspire future investigations into the dynamicity of social interactions, particularly during development, as this has the potential to reveal the intricacy of interaction behaviors. An example of how integrating mimicry into a broader view of interactions can provide new insights is explored below.

Mimicry as an Interpersonal Coordination Behavior

Placing behavioral mimicry in the big picture of interaction behaviors has the potential to elucidate the dynamic characteristics of these behaviors and help isolate the mechanisms underlying them. Recently, efforts have been made to reunite the interpersonal coordination literatures concerning behavioral mimicry and interactional synchrony (Lakin, 2013). Interpersonal coordination refers to the degree to which either the copying (i.e. mimicry) or temporal coupling (i.e. synchrony) of behaviors during interactions is non-random (Bernieri & Rosenthal, 1991). Importantly, both mimicry and synchrony contribute to liking and rapport during social interactions in adults (Lakin, 2013).

Like behavioral mimicry, synchrony as a form of interpersonal coordination has received limited attention in the developmental literature. The existent evidence indicates that, though to a lesser degree than adults, children are able to adjust their behavior timing to that of an adult partner by the age of 2.5 years (Kirschner & Tomasello, 2009) and with a same-aged peer by 4 years of age (Endedijk, Ramenzoni, et al., 2015). Synchrony continues to develop through middle childhood, as children increasingly synchronize their movements to those of a partner (Kleinspehn-Ammerlahn et al., 2011; Marsh et al., 2013). Intriguingly, several studies show a social sensitivity to synchronization earlier during development; twelve-month-olds tended to select a teddy bear that was rocked in synchrony with them over one that was rocked to a different beat (Tunçgenç, Cohen, & Fawcett, 2015) and 14-month-olds who were bounced in synchrony with an adult helped this adult more than an adult bouncing out of phase (Cirelli, Einarson, & Trainor, 2014; Cirelli, Wan, & Trainor, 2016). Similar effects have been found with respect to being copied. When 18-month-olds' actions were copied by an experimenter the infants later helped the adult more than when adults responded to the infants' actions with a different action (Carpenter, Uebel, & Tomasello, 2013) and 18-month-olds who observed an adult copy their actions on an identical set of toys, as compared to independently play with different toys, were later more likely to invite the adult to play (Fawcett & Liszkowski, 2012). Thus, whereas children begin to mimic (as documented in this thesis) and

synchronize with others themselves during early childhood, even infants seem to be sensitive to *being* copied or synchronized with.

This similarity in developmental trajectories of behavioral mimicry and synchrony implies that tracking both behaviors to identify commonalities and discrepancies could help pinpoint central social-neurocognitive mechanisms. As a case in point, infants' early sensitivity to *being* copied and synchronized with suggests that the social benefits of experiencing these behaviors could be partially underpinned by a common mechanism. In an adult experiment, Catmur and Heyes (2013) isolated a role of contingency in the social effects of being copied. Contingency entails a predictive relationship between the movements of two individuals and is thereby also a hallmark of synchrony. When participants' hand actions were contingently followed by either a hand or foot action (i.e. similar or dissimilar action), participants reported greater enjoyment of the task and closeness to a friend than when a hand action followed their hand action (i.e. always similar action) but not predictably (Catmur & Heyes, 2013). Hence, part of the social benefits of being mimicked could be a product of the contingent relationship between the mimicker's and mimickee's behaviors (though note that other studies in which contingency is kept constant across conditions also indicate the importance of similarity in the benefits of copying (e.g. Carpenter et al., 2013; Sparenberg et al., 2012)). A social role of contingency likely has its roots in early infancy, as infants are sensitive to the timing of their caregiver's behaviors (Gergely & Watson, 1999; Nadel, Carchon, Kervella, Marcelli, & Reserbat-Plantey, 1999; Tarabulsy, Tessier, & Kappas, 1996), and in turn, contingency is fundamental to forming (imitative) associations in perception-behavior mapping (Cook et al., 2014). It follows that contingency detection has been suggested to contribute to the positive effects of being copied in adults (Hale & Hamilton, 2016; Heyes, 2013). This example of being mimicked demonstrates that, as we gradually find more evidence of children's own production of mimicry in the future, integrating those findings into the wider literature of interaction behaviors will help us to understand mimicry's development and distinguish its underlying mechanisms.

Incorporating mimicry back into the (developmental) social interaction literature also obliges us to further scrutinize the experimental paradigms. In addition to the methodological concerns explored in the previous section, we need to determine whether we are truly measuring mimicry: do investigations into the social effects of being mimicked ensure that the level of contingency within the interaction is constant while only the presence or absence of mimicry varies between conditions? Inversely, what effect does the scripting of a confederate's behaviors have on the participants' perceptions of interactional contingency? Typically,

studies have focused on one side of the interaction, while keeping the other constant. For instance, this thesis specifically focused on children's production of mimicry and used videotaped models to control the other half of the interaction. Certainly, such basic investigations are necessary to first determine whether the target behaviors or effects can be identified (i.e. we first needed to study whether or not young children mimic). Yet, the above contingency example indicates that, through focusing on one half of the interaction, we might be unknowingly factoring out underlying mechanisms. Hence, even the ideal participant-confederate mimicry paradigm might not appropriately address future questions. Instead, to accurately understand dynamic social interactions, our experimental paradigms need start capturing this dynamicity, as that is ultimately where our research questions lie (Hari, Henriksson, Malinen, & Parkkonen, 2015; Sacheli, Aglioti, et al., 2015).

CONCLUDING REMARKS

In this thesis, I have shown that young children mimic and that the social sensitivity of their mimicry is a product of social-cognitive development. Underlying mimicry is the perception-behavior link, which is already dynamically modulated by the social relevance of the interactions during early childhood. When viewed as part of a greater literature, these findings provide initial stepping-stones: while they start to bridge the gaps in our knowledge of behavioral mimicry, they lay a foundation of questions that need to be answered in order to reach a structured understanding of this social interaction behavior, its neurocognitive mechanisms, and its dynamic development.

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English Summary

During social interactions, adults have been found to mimic the postures and mannerisms of one another. Though this behavioral mimicry occurs largely outside of awareness, it conveys an affiliative message to our interaction partners. The present thesis aimed to investigate how social behavioral mimicry develops during early childhood and to explore its developmental and neurocognitive mechanisms.

In *Chapter 2* we asked whether 3-year-olds display behavioral mimicry and whether their mimicry is already sensitive to the extent to which they might want to affiliate. In a video-based design, children observed either a helper or a hinderer scenario; when an adult model reached out to try to reach a toy, she was either helped by a second adult, who handed her the toy, or hindered by the second adult, who pulled the toy further away. This social manipulation was intended to indicate that the helper was a kind individual with whom a child might wish to affiliate whereas the hinderer was unkind and therefore someone a child would not want to befriend. Subsequently, the children observed either the helper or hinderer, dependent on condition, perform a range of meaningless behaviors, namely cheek scratching, mouth rubbing, head wiggling, yawning, and two facial expressions, laughing and frowning. Importantly, children were simply asked to watch the videos and were hence not instructed to copy these behaviors. In line with a mimicry effect, children performed five of the six behaviors more often while watching the behavior videos than during baseline. There was, however, no evidence for a social sensitivity in children's mimicry, as there were no differences in mimicry rates of children who observed the helper compared to those who observed the hinderer. Thus, this study presented the first evidence that children demonstrate mimicry like that reported in adults for a range of meaningless mannerisms, but left open the question of whether young children's mimicry is socially sensitive.

Chapter 3 went on to address the social sensitivity of mimicry in a developmental study with 3-year-olds and 4- to 6-year-olds. Building on *Chapter 2's* paradigm, we used novel groups based on color preference to affect the extent to which children would want to affiliate with the adult models. In a within-participants design, children observed both an in-group and an out-group model, each displaying two behaviors. The percentage of time children spent performing the behaviors while watching the videos was compared with the percentage of time they performed the behaviors during a preceding baseline to determine whether children mimicked. Replicating the findings from *Chapter 2*, 3-year-olds mimicked the behaviors but did so irrespective of which model performed them. Instead, the 4- to 6-year-olds mimicked selectively; they mimicked the in-group member significantly more than the out-group member. An

explicit liking measure reflected this developmental trajectory, as 4- to 6-year-olds but not 3-year-olds preferred to play with the in-group model. This study suggested that behavioral mimicry develops during the early childhood years. It was posited that as children's social understanding develops, so too would their use of implicit affiliative behaviors. Similarly, children's increasing inhibitory control during early childhood was put forth as playing a role in regulating the selectivity of children's social mimicry, as a socially specific mimicry effect was found in the older but not in the younger children of this study.

To explore these hypothesized roles of inhibitory control and social understanding in the production of social behavioral mimicry, we designed a novel mimicry paradigm in *Chapter 4*. Here, we combined a social manipulation of two live experimenters with a video-based experimental session during which the recorded experimenters displayed the target behaviors. This semi-live design ensured that the social manipulation was salient and that children could indeed affiliate with the experimenters, while also controlling for unintended differences in experimenter behavior during the experimental session. During the live session, the first experimenter shared one of two stickers with the participant whereas the second experimenter kept both stickers for herself. Subsequently, the 5-year-old participants observed the video session in which both the sticker sharer and sticker keeper told the child a story. A between-participants baseline was used in order to control for order and context effects on behavior rates; an experimental group observed the experimenters perform face and hand rubbing behaviors throughout the story session while the control group did not see these target behaviors. After the stories, children's inhibitory control was assessed using the day-night task and their social understanding was measured through a parental questionnaire. Comparing the experimental group's behavior percentages to the control group's indicated a significant suppression effect; overall, the experimental group negatively mimicked both the sharer and the keeper. Investigations into individual differences, though, revealed that children's social behavioral mimicry was related to inhibitory control and social understanding. The higher children's inhibitory control, the more they mimicked the keeper over than the sharer. Additionally, children's total mimicry was positively correlated to their social understanding. These findings suggested that behavior regulation plays a role in mimicry's navigation of complex social environments while social understanding is related to the emergence of this implicit affiliation behavior in general.

In an investigation into the social sensitivity of the possible neurocognitive basis of mimicry, *Chapter 5* explored whether a behavioral proxy of perception-behavior mapping was sensitive to social groups during early childhood. In the

motor interference task, the extent to which executed movements are interfered with by the simultaneous observation of incongruent movements is thought to be indicative of neurocognitive perception-behavior mapping. A tablet computer version of the motor interference task was adapted from Marshall and colleagues (2010). First, similar to the group procedure of *Chapter 3*, 4- to 6-year-olds gained membership to one of two novel groups based on their color preference. Following this group manipulation, children were instructed to use a stylus to draw a straight line back-and-forth on the tablet while it simultaneously displayed a stimulus video of a model moving her arm congruently or incongruently to the child's instructed direction. There were two within-participant manipulations of the stimulus videos, namely group membership of the model and whether or not her movement followed a biological velocity profile. How much children deviated into the uninstructed drawing direction was quantified as a measure of how much observing the models' behaviors interfered with executing their own behaviors. The motor interference effect was found only for the out-group trials and this was interpreted as a consequence of the coordinative nature of the task, which could have heightened attention towards interacting with an out-group member. The manipulation of velocity profile had little effect on children's motor interference, though this manipulation might have been too subtle. Thus, the study demonstrated that already during early childhood, the social characteristics of an interaction affect the degree of perception-behavior mapping.

Lastly, the study presented in *Chapter 6* was designed to test whether the mirror system could be involved in the production of behavioral mimicry. In contrast to the majority of the experimental contexts in which mirror system activity is demonstrated, in interactions in which individuals mimic they are not explicitly instructed to observe their interaction partner's subtle, meaningless mannerisms and postures. Hence, this study used single pulse TMS to measure mirroring during a naturalistic behavior observation task adapted from the behavioral mimicry literature. Motor evoked potentials (MEPs) in participants' right hands were measured as they observed stimulus videos of a model describing photographs. MEPs were recorded while models were and were not carrying out hand and leg behaviors that also differed in spatial extent (i.e. *large behaviors*: face rubbing and leg crossing; *small behaviors*: finger tapping and foot bouncing). Comparing the MEPs recorded during stimulus video observation with those from a nonsocial baseline demonstrated that, regardless of whether or not the models were performing a behavior, stimulus video MEPs were significantly higher. This suggested that simply observing an interaction partner in a typical communicative context enhanced mirroring effects. Additionally, comparing

the larger, more noticed behaviors, with the smaller, hardly noticed behaviors, revealed significant size effects. Hence, when an interaction partner's behavior is noticed, it seems that mirroring increases beyond the general arousal effect of observing a social partner. Together, these results suggest that behavioral mimicry is indeed supported by perception-behavior mapping, which is generally enhanced during social interactions and can thus, at times, lead to behavioral mimicry.

In conclusion, the presented studies shed light on both the developmental trajectory and mechanisms of behavioral mimicry. It was found that, while 3-year-olds mimic (*Chapters 2 and 3*), 4- to 6-year-olds' mimicry is sensitive to the social identity of their interaction partner (*Chapters 3 and 4*). The emergence of social behavioral mimicry is likely a product of developing behavioral regulation skills as well as a growing social understanding during early childhood (*Chapter 4*). In line with the presence of socially modulated mimicry in kindergartners, the extent of 4- to 6-year-olds' perception-behavior mapping is likely a dynamic product of the social interaction (*Chapter 5*). This perception-behavior mapping indeed seems to underlie behavioral mimicry, as in adults mirror system activity is enhanced during naturalistic social interactions in which mimicry would typically occur (*Chapter 6*).

Nederlandse Samenvatting

Tijdens sociale interacties spiegelen volwassenen vaak elkaars houdingen en gedragingen. Hoewel dit spiegelgedrag grotendeels gebeurt zonder dat we het doorhebben, laat het onze interactiepartner zien dat we ons met hen willen affiliëren. De doelstellingen van dit proefschrift waren om te bestuderen hoe dit sociale spiegelgedrag ontwikkelt tijdens de vroege kindertijd en om de onderliggende ontwikkelings- en neurocognitieve mechanismen te onderzoeken.

In *Hoofdstuk 2* onderzochten wij of 3-jarigen spiegelgedrag vertonen en of dit spiegelgedrag al gevoelig is voor de sociale context waarin het gebeurt. Kinderen keken naar een filmpje van iemand die óf iemand anders hielp óf iemand anders hinderde: wanneer een volwassene een knuffel probeerde te pakken, hielp een tweede volwassene haar daarbij door de knuffel aan te geven of hinderde ze haar juist door de knuffel af te pakken. Het doel van deze sociale manipulatie was om aan de kinderen te laten zien dat de helper een aardig persoon is waarmee ze zich mogelijk willen affiliëren of dat de hideraar een onaardig persoon is waarmee ze geen vrienden willen zijn. Nadat de kinderen dit filmpje hadden gezien, zagen ze de helper of hideraar, afhankelijk van de conditie, een aantal gedragingen uitvoeren, namelijk aan de wang krabben, over de mond wrijven, het hoofd heen en weer schudden, gapen, lachen en fronzen. De kinderen werden alleen gevraagd om naar de filmpjes te kijken en kregen dus geen instructies om deze gedragingen na te doen. Uit de resultaten blijkt dat kinderen spiegelgedrag vertoonden: ze voerden vijf van de zes gedragingen vaker uit terwijl ze naar het filmpje keken dan tijdens een controleperiode aan het begin van het onderzoek. Er was echter geen effect van de sociale context: kinderen spiegelden het gedrag van de helper even vaak als het gedrag van de hideraar. Deze studie laat dus voor de eerste keer bewijs zien voor spiegelgedrag bij jonge kinderen, maar is het nog onduidelijk wanneer de sociale gevoeligheid van spiegelgedrag ontwikkelt.

Hoofdstuk 3 onderzocht de sociale gevoeligheid van spiegelgedrag bij kinderen van 3 en 4 tot 6 jaar. Dezelfde gedragsfilmpjes als in *Hoofdstuk 2* werden gebruikt in combinatie met een groepsmanipulatie. Nadat kinderen op basis van hun voorkeur voor een kleur ingedeeld werden in een groep, zagen kinderen een vrouw uit hun eigen kleurgroep twee gedragingen uitvoeren en een vrouw uit een andere kleurgroep twee andere gedragingen uitvoeren. Om spiegelgedrag vast te stellen, werd gemeten hoe lang (als percentage van de totale tijd) kinderen de gedragingen uitvoerden tijdens het kijken naar gedragsfilmpjes in vergelijking met een controleperiode aan het begin van het onderzoek. Dit liet zien dat 3-jarigen de gedragingen spiegelden, net als in *Hoofdstuk 2*. De 4- tot 6-jarigen spiegelden ook, maar deden dat specifiek: ze spiegelden het gedrag van de vrouw uit hun eigen groep meer dan het gedrag van de vrouw uit de

andere groep. Deze voorkeur was ook terug te vinden in een vraag over met wie de kinderen zouden willen spelen. De 4- tot 6-jarigen, maar niet de 3-jarigen, kozen hierbij vaker voor de vrouw uit hun eigen groep. Deze studie suggereert dat de sociale gevoeligheid van spiegelgedrag zich tijdens de vroege kindertijd ontwikkelt. Op basis van deze resultaten werden twee hypothesen opgesteld. Ten eerste werd gesteld dat naar mate kinderen sociaal begrip ontwikkelen, ze ook sociaal spiegelgedrag ontwikkelen. Ten tweede werd verondersteld dat gedragsinhibitie belangrijk is in het reguleren van de sociale afstemming van spiegelgedrag.

Om deze twee hypothesen over de rollen van sociaal begrip en gedragsinhibitie in sociaal spiegelgedrag te toetsen, werd in *Hoofdstuk 4* een nieuwe onderzoeksopzet ontwikkeld. Tijdens een sociale manipulatie aan het begin deelde één vrouwelijke onderzoeksleider één van haar twee stickers met het kind, terwijl een andere vrouwelijke onderzoeksleider beide stickers zelf hield. Daarna keek het kind naar een filmpje waarin beide onderzoekers een verhaal aan het kind vertelden. Kinderen werden verdeeld over twee groepen; de experimentele groep zag de onderzoekers gedragingen uitvoeren terwijl ze de verhaaltjes vertelden, terwijl de controlegroep deze gedragingen niet zag tijdens de verhaaltjes. Na de verhaaltjes werd gedragsinhibitie gemeten door middel van de dag-nacht taak en werd sociaal begrip van de kinderen gemeten met een vragenlijst voor de ouders. Een vergelijking van de gedragingen in de twee groepen liet zien dat kinderen in de experimentele groep de gedragingen minder vaak uitvoerden dan kinderen in de controle groep, hetgeen suggereert dat het effect van spiegelgedrag omgekeerd was. Verdere analyses gericht op individuele verschillen lieten echter zien dat het spiegelgedrag van de kinderen gerelateerd was aan gedragsinhibitie en sociaal begrip. Hoe meer gedragsinhibitie, des te meer de kinderen in de experimentele groep de onderzoeksleider die beide stickers zelf hield spiegelde dan de delende onderzoeksleider. Ook was er een positieve correlatie tussen hoeveel kinderen spiegelde en hun sociaal begrip. Deze bevindingen laten zien dat gedragsinhibitie en sociaal begrip een rol spelen in de ontwikkeling van sociaal spiegelgedrag tijdens de vroege kindertijd.

Hoofdstuk 5 beschrijft een onderzoek naar de sociale gevoeligheid van de vermoedelijke neurocognitieve basis van spiegelgedrag. Onderzocht werd of een gedragsmaat dat gerelateerd wordt aan het neurale spiegelnetwerk gevoelig is voor sociale groepen bij jonge kinderen. In de motor-interferentie taak wordt gemeten in welke mate het uitvoeren van een actie beïnvloed wordt door het tegelijkertijd observeren van een soortgelijke actie. Net als in *Hoofdstuk 3* mochten kinderen eerst een groep kiezen op basis van hun voorkeur voor

een kleur. Daarna kregen ze de instructie om steeds een rechte lijn heen en weer te tekenen op het scherm van een tabletcomputer. Terwijl de kinderen tekenden, werden er op de tablet filmpjes afgespeeld waarin een vrouw haar arm heen en weer bewoog in dezelfde (bijvoorbeeld horizontale) of een andere (bijvoorbeeld verticale) richting als waarin het kind tekende. De filmpjes lieten óf een vrouw uit dezelfde groep als het kind óf een vrouw uit de andere groep dan het kind zien die op een normale biologische manier of juist op een biologisch onmogelijke manier haar arm bewoog. Hoeveel de getekende lijnen van de kinderen afweken in de niet-geïnstrueerde richting werd gebruikt als een maat voor motor-interferentie. Uit de resultaten bleek dat kinderen alleen motor-interferentie vertoonden als de persoon in het filmpje tot de andere groep behoorde. Omdat ze samen moesten bewegen met iemand uit een andere groep, kan het zijn dat kinderen tijdens deze conditie extra aandachtig waren voor hun interactiepartner. Deze studie suggereert dat de activiteit van het neurale spiegelnetwerk kan variëren, afhankelijk van de sociale context waarin het gebeurt.

Het onderzoek in *Hoofdstuk 6* had als doel om de rol van het neurale spiegelnetwerk in de aansturing van spiegelgedrag te bestuderen. Meestal wordt de activiteit van het spiegelnetwerk gemeten tijdens taken waarbij de aandacht van de proefpersonen specifiek gericht is op het observeren van eenvoudige, doelgerichte handelingen. Tijdens natuurlijke interacties waarin spiegelgedrag voorkomt, is dit echter niet het geval. Daarom werd er in dit onderzoek gebruik gemaakt van transcraniële magnetische stimulatie (TMS) om spiegelnetwerk activiteit te meten terwijl de proefpersonen een taak uitvoerden waarbij hun aandacht niet per se gericht was op de subtiele bewegingen van hun interactiepartners, net als tijdens typische sociale interacties. Als maat van activiteit van het spiegelnetwerk werden zogeheten motor evoked potentials (MEPs) teweeggebracht met TMS pulsen boven de motor cortex van de volwassen proefpersonen. Deze MEPs werden gemeten terwijl proefpersonen filmpjes keken waarin iemand plaatjes beschreef die de proefpersonen later moesten herkennen zowel op momenten dat de persoon in het filmpje een gedraging uitvoerde (grote gedragingen: gezicht wrijven, benen over elkaar slaan; kleine gedragingen: vinger op en neer bewegen, voet op en neer bewegen) en op momenten waarop dat niet het geval was. Een vergelijking van deze MEPs met MEPs die gemeten waren tijdens een niet-sociale controleconditie liet zien dat, ongeacht of de persoon in de filmpjes een gedraging uitvoerde op het moment van de MEP meting of niet, MEPs tijdens de sociale observatie groter waren dan tijdens de controleconditie. Dit laat zien dat het simpelweg observeren van een ander persoon in een interactiecontext leidt tot hogere activiteit van het spiegelnetwerk. Daarnaast was er een effect van grote van de gedragingen.

MEPs gemeten terwijl proefpersonen de twee grote gedragingen zagen waren groter dan die van de twee kleine gedragingen, wat suggereert dat als een gedraging opgemerkt wordt, deze tot extra activatie leidt bovenop de algemene toename in activatie. Samen suggereren deze bevindingen dat het neurale spiegelnetwerk spiegelgedrag ondersteunt omdat de activatie van dit netwerk toeneemt tijdens sociale interactie. In sommige gevallen zou dat kunnen leiden tot het daadwerkelijk uitvoeren van de geobserveerde gedraging.

Samen geven deze studies nieuwe inzichten in zowel de ontwikkeling als in de mechanismen van spiegelgedrag. Terwijl 3-jarigen spiegelgedrag al vertonen (*Hoofdstukken 2 en 3*), wordt spiegelgedrag pas rond de leeftijd van 4 tot 6 aangepast aan de sociale context waarin het plaatsvindt (*Hoofdstukken 3 en 4*). De ontwikkeling van dit sociaal-gevoelige spiegelgedrag is waarschijnlijk een resultaat van zowel een toename in sociaal begrip en een verbetering van gedragsinhibitie (*Hoofdstuk 4*). Waarschijnlijk ligt het neurale spiegelnetwerk ten grondslag aan sociaal spiegelgedrag (*Hoofdstuk 6*) en is de activiteit van dit netwerk al bij 4- tot 6-jarigen gevoelig voor de sociale context waarin het gedrag wordt geobserveerd.

Curriculum Vitae

Johanna Elizabeth van Schaik was born on May 9th, 1989 in Zeist, the Netherlands. In 2007, Jo started her studies in cognitive neuroscience, biology, and psychology at University College Utrecht, from which she graduated with an honors BSc cum laude in 2010. She went on to study cognitive neuroscience at Radboud University Nijmegen and obtained her MSc cum laude in 2012. In the same year, Jo was awarded the Donders Institute's TopTalent PhD grant to continue her research on behavioral mimicry under the supervision of Sabine Hunnius, Harold Bekkering, and Ivan Toni. During her PhD, she received grants from the Federation of European Neuroscience Societies and the Erasmus+ Program to conduct one of her research projects (*Chapter 6*) at Sapienza University of Rome, Italy, with Salvatore Aglioti and Lucia Sacheli. In 2016, Jo was awarded a grant from the Netherlands Initiative for Education Research (NRO), a part of the Netherlands Organization for Scientific Research (NWO), to continue her career as a post-doctoral researcher at Leiden University. Working with Maartje Raijmakers in the Brain and Education Lab, Jo is investigating young children's formation and updating of science concepts in hands-on learning contexts.

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