COPY THE MEANS OR COPY THE GOAL:
INDIVIDUAL DIFFERENCES AND DEVELOPMENTAL CHANGES
IN YOUNG CHILDREN'S IMITATIVE BEHAVIOR

A Dissertation

Presented to the Faculty of the Graduate School

of Cornell University

In Partial Fulfillment of the Requirements for the Degree of

Doctor of Philosophy

by

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August 2015

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INDIVIDUAL DIFFERENCES AND DEVELOPMENTAL CHANGES

IN YOUNG CHILDREN'S IMITATIVE BEHAVIOR

Yue Yu, Ph. D.

Cornell University 2012

For young children, imitation serves both a learning role to gain knowledge and skills, and a social role to connect with people. Research on young children's imitative behavior has presented a dilemma: On one hand infants and young children engage in goal-directed imitation, in which they selectively copy the model's goal, or actions that are necessary for achieving the goal. On the other hand they engage in faithful imitation or "overimitation", in which they also copy the exact manner of actions, or actions that are apparently unnecessary for achieving the goal. In this dissertation I approach this dilemma from an individual difference perspective. Two cohorts of children (N = 48) visited the lab on 3 occasions. Each time, children were tested on two types of imitation tasks, as well as tasks measuring other aspects of development. Parents filled out questionnaires about their children. Results from children's three visit showed stable individual differences in children's imitative behavior both within and between different types of tasks. Correlations between imitation measurements revealed two factors: one for goal-directed imitation and one for means-directed imitation. These two factors are correlated but also distinctive: goal-directed imitation is associated with children's general developmental level, Theory-of-Mind and prosocial behavior at 24 and 30 months; means-directed imitation is associated with children's executive functioning and normative reasoning at 36 months. In terms of developmental trajectory, there is a significant increase in means-directed imitation between 30 and 36 months of age, which coincide with an increase in children's normative reasoning. These results are discussed in terms of their implications for understanding children's social learning mechanisms, and also in terms of continuity in individual differences among infants and young children.

BIOGRAPHICAL SKETCH

Yue Yu was born in Shanghai, China and received his B.A. from Beijing University. His early work examined social cognitive skills in typically developing children and children with autism. After joining the Cornell Early Childhood Cognition Lab, he became interested in understanding young children's social learning and imitation. He was also involved with Cornell Outdoor Education and served as an instructor for several outdoor classes.

ACKNOWLEDGEMENTS

I would not be able to complete my dissertation without support from my committee members, lab members, family and friends. It is difficult to pin down the extent of my gratitude to a simple acknowledgments page.

I consider myself extremely lucky to have Dr. Tamar Kushnir as my committee chair. Her advices in both research and professional development guided my way towards a good researcher, and her enthusiasm and warmth kept me motivated and confident in myself. I am very grateful to Dr. Marianella Casasola for sharing her lab resources, and her loud laughter always lights up the basement. I benefitted a lot from Dr. Steve Robertson's comments in meetings and classes, to the extent that I took his infant development course twice (and if not for the need to focus on dissertation, I would have taken it a third time). Finally, Dr. Jim Booth is extremely approachable and helpful when I have questions about statistics.

My research assistants have shown great intellectual abilities and work ethics from which my dissertation project have immensely benefitted, and many of them have stayed with me throughout this longitudinal project. Among the people I have to thank are SItha Aribindi, Sydney Beck, Michelle Elsner, Sara Gager, Nancy Ha, Kelly Jirka, Mike Johnson, Jennifer Lambert, Jasmine LaCoursiere, Maria Lee, Nisha Patel, Alicia Ramirez, and Kimberly Senko.

The many friends in my lab and in my department provided valuable guidance and feedback on my dissertation. I want to thank Nadia Chernyak, Youjeong Park, and Jessie Koh for sharing experiences on writing and defending dissertation, and I want to thank Christopher Vredenburgh, Carrisa Kang, Alice Zhao, and other lab members for commenting on my dissertation.

In many ways, my family is the group of individuals to whom I owe the most, and they always support me and cheer me up when I am in a low mood. And finally, I want to thank Yang Yang for her tolerance for my frustrations during the past few weeks, even when she is under great stress herself.

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CHAPTER 1

INTRODUCTION

Imitation underlies two of the major missions children face: to learn about the world, and to connect with people. On one hand, imitation serves as a canonic form of social learning. Children imitate to learn a variety of skills, including tool use, norms and conventions, language, etc. (Want & Harris, 2002). On the other hand, imitation also facilitates social interaction. It helps to build trust, identification, and affiliation between people (Chartrand & Bargh, 1999; Over & Carpenter, 2013). Related to these different functions, imitation also takes different forms. In the introduction chapter I first discuss how imitation is defined for the purpose of this dissertation. I then introduce two lines of research, one of which shows children's imitation is goal-directed and the other shows children's imitation is faithful. Next I present research discussing the influencing factors of goal-directed and faithful imitation, including those regarding the model, the context, and the child. I then introduce major theories that try to explain goal-directed and faithful imitation. Finally, I state the specific objectives for this dissertation, and the method I chose to achieve these objectives.

Definitions

Imitation is a rather broad term, and is used in different ways in different subfields of psychology (Hurley & Chater, 2005). For the purpose of this dissertation, the use of the term "imitation" is restrained by the following criteria: First, I focus on the imitation of actions, as oppose to imitation of language (Kuhl & Meltzoff, 1996), abstract strategies (Williamson, Jaswal, & Meltzoff, 2010), structure in actions (Whiten, 2002), norms, opinions, or attitudes (Over & Carpenter, 2012). Second, some researchers have suggested a novelty criterion for true imitation, which states that the modeled action should be novel in the sense that it has to be outside the individual's behavioral repertoire (Byrne & Tomasello, 1995; Galef Jr, 1988; Thorpe, 1963; Tomasello, Kruger, & Ratner, 1993). This type of learning when a new behavioral complex is acquired is called *production learning* (Janik & Slater, 2000). Here I adopt the loosened criterion which allows *contextual learning*—the learning when a familiar behavior is applied in novel circumstances (Heyes, 1995)—to qualify imitation. Third, imitation has been examined in both passive and active ways, and in this dissertation I focus on active imitation. I do not discuss unconscious matching of behavior, which is sometimes referred to as "automatic imitation" or "unconscious mimicry" in social psychology literature (reviewed in Chartrand & van Baaren, 2009; Heyes, 2011), or "response facilitation" in comparative psychology literature (Tomasello, et al., 1993). Finally, I focus on object-related imitation, as opposed to gestural imitation (e.g., Bekkering, Wohlschlager, & Gattis, 2000).

As an additional note, children do not always imitate in response to a model's demonstration. They frequently engage in other forms of social learning such as emulation, exploration, and innovation (McGuigan & Whiten, 2009; Yu & Kushnir, 2011). In this dissertation I use the term “imitative behavior” to broadly refer to children’s responses in the imitation tasks, and it is not restricted to goal-directed and faithful imitation (although these two will be my focus).

Goal-directed Imitation

Awareness of the goals of people’s actions appears in the first half year of life (Woodward, 1998). Starting from 7 to 14 months of age, infants demonstrate their understanding of other’s goals by imitating selectively; they choose to copy intentional actions over actions that are performed accidentally, or actions that are ambiguous in their goal (Carpenter, Akhtar, & Tomasello, 1998; Carpenter, Call, & Tomasello, 2002; Hamlin, Hallinan, & Woodward, 2008). Infants also select new actions that meet the model’s goals after being shown failed attempts at achieving them (Bellagamba, Camaioni, & Colonnesi, 2006; Meltzoff, 1995; Nielsen, 2009). It should be noted that goals of actions can be hierarchically organized—in the absence of an obvious external goal, children are more likely to copy the manner of a model’s action, thus perhaps inferring that to be the goal (Bekkering, et al., 2000; Carpenter, Call, & Tomasello, 2005). Children also infer the goal of an action based on whether the action is freely chosen, or whether it is forced by environmental constraints. They then imitate accordingly (Gergely, Bekkering, & Király, 2002).

Goal-directed imitation can also demonstrate children’s developing causal knowledge—children are often more likely to imitate causally relevant acts than irrelevant ones (Brugger, Lariviere, Mumme, & Bushnell, 2007; Buchsbaum, Gopnik, Griffiths, & Shafto, 2011; DiYanni & Kelemen, 2008; Harnick, 1978; Williamson & Markman, 2006; Williamson, Meltzoff, & Markman, 2008). They are also more likely to explore on their own when causal outcomes are ambiguous (Schulz, Hooppell, & Jenkins, 2008).

Faithful Imitation

A different line of research has documented an opposite tendency in children's imitation—that they are faithful to the model's actions even when these actions are both irrelevant to achieving goals and causally unnecessary. This tendency is sometimes referred to as "overimitation" (Lyons, Young, & Keil, 2007), "blind imitation" (Want & Harris, 2002), or "faithful imitation" (Over & Carpenter, 2012). In this dissertation I use the term "faithful imitation" because it is a neutral description of the behavior, and does not imply that the behavior is irrational. Several studies have documented that children ranging from 2 to 5 years of age faithfully reproduce inefficient solutions to a tool-using task, despite the availability of a more efficient solution (Horner & Whiten, 2005; Lyons, et al., 2007; McGuigan, Whiten, Flynn, & Horner, 2007; Nagell, Olguin, & Tomasello, 1993; Nielsen, 2006). They also unnecessarily copy the specific "style" of the demonstrator's action (Call, Carpenter, & Tomasello, 2005; Meltzoff, 1988), and stick to the demonstrator's method when different methods could be applied to achieve the same result (Whiten, Custance, Gomez, Teixidor, & Bard, 1996). Indeed, such tendency to faithfully imitate all aspects of all actions has been shown across many studies using different methods, and in a variety of cultures and contexts (Kenward, 2012; Kenward, Karlsson, & Persson, 2011; Keupp, Behne, & Rakoczy, 2013; Keupp, Behne, Zachow, Kasbohm, & Rakoczy, 2015; Lyons, Damrosch, Lin, Macris, & Keil, 2011; McGuigan, Makinson, & Whiten, 2011; Nielsen & Blank, 2011; Nielsen, Moore, & Mohamedally, 2012; Nielsen, Mushin, Tomaselli, & Whiten, 2014; Nielsen, Simcock, & Jenkins, 2008; Nielsen & Tomaselli, 2010; Simpson & Riggs, 2011; Watson-Jones, Legare, Whitehouse, & Clegg, 2014; Yu & Kushnir, 2014). Importantly, children do not reproduce those actions merely because they mistaken them as being causally relevant, because they verbally report those actions as unnecessary for achieving the goal before or after copying them (Kenward, et al., 2011; Yu & Kushnir, 2014).

I should clarify here that since the research on goal-directed and faithful imitation follows two separate traditions, these two types of imitative behavior are not mutually exclusive. Actually, in most of the abovementioned studies, faithful imitation implies copying both the means and the goal, or copying both the unnecessary and the necessary actions. In these studies the definitions of faithful imitation and goal-directed imitation overlap. On the other hand, some of the abovementioned studies do solely focus on imitation of the action means or unnecessary actions (e.g., Keupp, et al., 2013; Keupp, et al., 2015; Nielsen, 2006). In these cases what have been coded as “faithful imitation” or “overimitation” are probably better described as “imitating irrelevant components” or “means-directed imitation”, and does not imply imitation of the goal or the necessary actions. In the rest of the literature review I will not differentiate between these two types of faithful imitation, as they are often used interchangeably in the literature. However, this distinction is important for my study, and I will discuss more when I describe my research objectives.

Factors that Influence Goal-directed and Faithful Imitation

A number of factors have been identified to influence how goal-directed and faithful children imitate in a particular task. Most of these factors can be categorized into three groups: the model, the context, and the child.

The Model

A key factor that influences how children copy is who they copy. Indeed, children take account of the “who” factor on several levels: Is the model a video image, or is it a living person? If the model is a person, what is his or her knowledge state, group membership, and intention? Am I performing the actions in front of the model?

Research has show that children imitate more faithfully in response to living demonstrators rather than video (McGuigan, et al., 2007; Nielsen, et al., 2008). For living demonstrators, children are more likely to imitate competent or reliable demonstrators (Buchsbaum, et al., 2011; DiYanni & Kelemen, 2008; Koenig, Clément, & Harris, 2004; Wilks, Collier-Baker, & Nielsen, 2014; Zmyj, Buttelmann, Carpenter, & Daum, 2010), as well as adult demonstrators (Wood, Kendal, & Flynn, 2012). They are also more likely to imitate the actions demonstrated by the majority of demonstrators rather than the minority (Flynn & Whiten, 2010; Haun, Rekers, & Tomasello, 2012; Haun, Van Leeuwen, & Edelson, 2013; Herrmann, Legare, Harris, & Whitehouse, 2013; Whiten & Flynn, 2010; Wilks, et al., 2014), and they imitate in-group members over out-group members (Kinzler, Corriveau, & Harris, 2011). For the same demonstrator, children imitate more faithfully when he or she plays with them (Nielsen, 2006) or talks to them (Brugger, et al., 2007). Toddlers and preschoolers also imitate more faithfully after pedagogical versus non-pedagogical demonstrations (Bonawitz et al., 2011; Southgate, Chevallier, & Csibra, 2009). Indeed, the mere presence of eye-contact increases imitation in both infants (Király, Csibra, & Gergely, 2004) and adults (Wang, Newport, & Hamilton, 2011). Finally, children imitate more faithfully in the presence of the specific individual demonstrator over new individuals (Király, 2009; Nielsen & Blank, 2011).

The Context

Research has shown that even very slight modifications in the social context can significantly change children's inferences about and motivation for the imitation task, thus changing how they imitate.

Prior social interactions with a demonstrator can change children's inference about the overarching goal of the entire interaction. For example, when a prior interaction emphasized the demonstrator's goal to retrieve a reward, children are more goal-directed in the subsequence imitation task (Carpenter, et al., 2002; Yu & Kushnir, 2014). On the other hand, if the prior interaction emphasized copying, children are more faithful in the imitation task (Yu & Kushnir, 2014). Similarly, children modify their own imitative behavior, as well as critique of a third-party's imitative behavior, based on whether the demonstrator verbally emphasizes a physical goal ("have a go and find a puzzle piece") or a social convention ("have a go and dax") (Keupp, et al., 2015).

The type of action sequences can also change children's inferences and responses in an imitation task. Watson-Jones and colleagues (2014) distinguished two types of action sequences: instrumental (action sequence with a different start- and end-state) versus social conventional (action sequence with an identical start- and end-state). They showed that imitative fidelity is higher for social conventional action sequences than for instrumental action sequences. Moreover, framing an action sequence as instrumental (e.g., "I am going to make a necklace.") or conventional (e.g., "Everyone always does it this way.") exerts a similar effect (Clegg, 2013).

Besides inferences, context can also impact imitative behavior through changing children's motivation. For example, Over and Carpenter (2009) found that 5-year-old children who were primed with ostracism are more likely to copy the irrelevant actions of a demonstrator than children who were given a neutral prime. One explanation is that the threat of ostracism promotes motivation to seek affiliation through high fidelity imitation. Furthermore, contextual effects on children's inferences and motivation may interact with each other—for example, third-party ostracism has a larger effect for imitation fidelity of a conventional action sequence, rather than an instrumental action sequence (Watson-Jones, et al., 2014).

The Child

As the subject of imitation, the child's intrinsic capacities and motivations certainly have a role on how he or she imitates. However, relatively little research has focused on this piece of the puzzle. Until now, the one intrinsic factor that has been associated with imitative behavior is age, and other intrinsic factors have just started to emerge.

There are some indications that imitation in general, and faithful imitation in particular, increases with age (Užgiris, 1981). Studies which focus on infants tend to show goal-directed imitation (Brugger, et al., 2007; Carpenter, et al., 1998; Gergely, et al., 2002; McGuigan & Whiten, 2009; Meltzoff, 1995; Zmyj, et al., 2010), and studies which focus on preschoolers and older children tend to show faithful imitation (Horner & Whiten, 2005; Kenward, 2012; Kenward, et al., 2011; Keupp, et al., 2013; Keupp, et al., 2015; Lyons, et al., 2011; Lyons, et al., 2007; McGuigan, et al., 2011; Nagell, et al., 1993; Nielsen & Blank, 2011; Nielsen, et al., 2012; Nielsen, et al., 2014; Nielsen, et al., 2008; Nielsen & Tomaselli, 2010; Simpson & Riggs, 2011; Watson-Jones, et al., 2014; Yu & Kushnir, 2014). However there are also studies showing faithful imitation in infants and toddlers (Hilbrink, Sakkalou, Ellis-Davies, Fowler, & Gattis, 2013; Nielsen, 2006), as well as showing goal-directed imitation in preschoolers (Bekkering, et al., 2000; DiYanni

& Kelemen, 2008; Want & Harris, 2001) and even adults (Horowitz, 2003). Note that the paradigms employed in these studies vary in a great extent, so they do not provide strong evidence for a direct age comparison.

A few studies have directly compared different age groups in the same context using the same imitation tasks. McGuigan and colleagues (2009; 2007) showed a group of toddlers (23- and 30-month-olds) and a group of preschoolers (3- and 5-year-olds) a same puzzle box that contained a reward. A sequence of actions was demonstrated for the puzzle box, which included a set of actions that was irrelevant for attaining the reward, a set of relevant actions, and the retrieval of the reward. Results showed that when children were given a chance to operate the puzzle box, 3- and 5-year-olds copied most of the irrelevant actions, whereas 23- and 30-month-olds rarely copied the irrelevant actions. Our study (Yu & Kushnir, 2014) also found that 4-year-olds imitate more faithfully than 2-year-olds in a same puzzle box task. Further studies are needed to confirm the age trend; and more importantly, to pin down how faithful imitation develops in *individual* children.

Few studies have explored how imitation is influenced by intrinsic factors other than age. One such example is the recent work of Hilbrink and colleagues (2013). They followed a group of infants from 12 to 15 months of age, assessed their imitative behavior using puzzle box tasks, and collected parental report on children's temperament (using Early Childhood Behavior Questionnaire). Results showed that faithful imitation increased from 12 to 15 months, and infants high in extraversion were more faithful imitators than infants low in extraversion. Another recent study suggests that children's impulsivity, shyness, and their popularity and dominance in a classroom also affected the outcome of their imitative learning (Flynn & Whiten, 2012). These studies points to an interesting direction to situate imitative behavior in a broader context of development, and suggest that individual differences in imitation may exist, and may be related to other aspects of cognitive and social development.

Theories on Goal-directed and Faithful Imitation

Related to the multi-facet empirical evidence discussed above, much debate has been going on about why children engage in goal-directed imitation in some circumstances and engage in faithful imitation in others. Among the major theories being proposed, the hierarchical goals account focuses primarily on explaining goal-directed imitation; the causal confusion accounts, natural pedagogy account and normativity account focus primarily on explaining faithful imitation; and the dual-functioning account aims to explain both goal-directed and faithful imitation.

Hierarchical Goals Account

Children's selectivity in imitating effective and goal-directed actions has often been attributed to their understanding about the model's mental states (Tomasello, et al., 1993). In one version of these accounts, Bekkering and colleagues (2000) argue that observed actions are broken down and then reconstructed in terms of their goals. The goals are represented in a hierarchical fashion, so that goals at the top of the hierarchy are imitated accurately and goals further down the hierarchy are neglected. This explains why children selectively imitate the end-state of an action when that end-state is salient, and accurately imitate the manner of the action when the end-state is not salient (Bekkering, et al., 2000; Carpenter, et al., 2005; Perra & Gattis, 2008). One shortcoming of this account is it cannot easily explain faithful imitation—that children reproduce irrelevant actions even when the goal of the action sequence is clear.

Causal Confusion Accounts

The causal confusion accounts suggest that children imitate faithfully because they are confused about the causal relationship between the irrelevant action and the goal. One version of it is the "Automatic Causal Encoding, ACE" account (Lyons, et al., 2011; Lyons, et al., 2007). According to this account, when children observe a causally irrelevant action on an object, they revise their implicit understanding of the causal relations behind the demonstration, and interpret the action as causally relevant. This reevaluation leads them to produce faithful reproductions of modeled behavior even in cases where the actions appear to be clearly unnecessary. Evidence for this account mainly comes from the robustness in children's faithful imitation. For example, children imitated the irrelevant actions despite the experimenter's explicit instruction not to perform "silly" actions (Lyons, et al., 2007). Children also continued to perform the irrelevant actions under time pressure and in competitive situations (Lyons, et al., 2011).

The authors conclude that faithful imitation is "unavoidable" because children truly believe what they did were causally necessary.

Whiten and colleagues (Whiten, Horner, & Marshall-Pescini, 2005; Whiten, McGuigan, Marshall-Pescini, & Hopper, 2009) have proposed a similar "copy-all, correct-later" account from an evolutionary perspective. According to this account, children copy the actions of others exactly because in most cases this is the most efficient way to learn causally opaque cultural artifacts. The small percentage of irrelevant actions can be eliminated later through individual learning. The automaticity of this system means that children copy actions faithfully even when it appears irrational for them to do so.

These accounts are challenged by recent empirical evidences. For one, faithful imitation is far from "unavoidable". As discussed above, a number of contextual factors changes children's fidelity in imitation. Also, before or after 4- and 5-year-old children imitate faithfully in the puzzle box task, they verbally report that they can retrieve the reward without performing the irrelevant action (Kenward, et al., 2011; Yu & Kushnir, 2014).

Natural Pedagogy Account

Related to the causal confusion accounts, the natural pedagogy account (Csibra & Gergely, 2006, 2009) suggests that children's tendency to faithfully copy actions is due to an innate pedagogical learning system which allows for fast transfer of information between individuals. According to this account, pedagogical cues such as eye contact and child-directed speech lead children to infer that the information about to be communicated is important and generalizable cultural knowledge. When ostensive cues are present, and a model produces his or her actions freely and intentionally, children automatically encode the demonstrated actions as important to copy, regardless of whether they seem to be irrelevant to the task at hand. Support for this account comes from studies which show changes in children's imitative behavior due to the presence of pedagogical cues, such as eye-contact (Király, et al., 2004) and child directed speech (Brugger, et al., 2007).

Normativity Account

According to the normativity account, children do understand that some actions are causally irrelevant, but under certain circumstances they view these elements as conventionally essential parts of bigger activities, and faithfully copy them (Herrmann, et al., 2013; Kenward, 2012; Keupp, et al., 2013). Starting from about 2 to 3 years of age, children become increasingly sensitive to the normative structure of artifact functions (Casler, Terziyan, & Greene, 2009; Wohlgelernter, Diesendruck, & Markson, 2010), conventional activities (Rakoczy, 2008; Rakoczy, Warneken, & Tomasello, 2008; Schmidt, Rakoczy, & Tomasello, 2011) and language (Beller, 2010; Cummins, 1996; Harris & Núntez, 1996). This sensitivity leads to conventional thinking in imitation tasks. In a recent study (Kenward, 2012), after 3- and 5-year-olds together with a puppet observed an adult demonstrate instrumental tasks that include unnecessary actions, the majority of the children spontaneously protested the subsequent failure of the puppet to perform the unnecessary action. Children also imitate more faithfully when the action itself is labeled (e.g., as “daxing”) (Keupp, et al., 2013), and when the demonstrator instruct children to follow a social convention (Keupp, et al., 2015). Therefore, children may view unnecessary actions as conventional norms that reflect either conventional uses of novel apparatuses, or rules set up for the particular game.

Dual-functioning Account

The dual-functioning account was coined by Užgiris (1981), and recently elaborated by Over and Carpenter (2012, 2013). The main idea of this account is that imitation serves both a learning function and a social function, and children imitate differently based on whether the learning function or the social function predominates the scenario. According to Over and Carpenter (2012), when the learning function predominates, children focus more on the characteristics of the task, and thus tend to selectively imitate actions that are relevant for achieving a particular effect. When the social function predominates, children seek to affiliate with the model by faithfully copy all aspects of his or her actions, irrespective of their causal relevancy.

Evidence compatible with this position comes from studies showing that imitation fidelity increases with the need to affiliate with the model. For example, children imitate more faithfully when primed with ostracism (Over & Carpenter, 2009; Watson-Jones, et al., 2014), and when the model is socially responsive (Nielsen, 2006). The absence of the model who had performed the irrelevant step decreases children's fidelity in imitation (Nielsen & Blank, 2011). Also, children who had first discovered by themselves an efficient method of how to retrieve a reward then switched to a more complicated method after a model had demonstrated this complicated method (Nielsen & Tomaselli, 2010). The social affiliation role of imitation is also evident in "synchronic imitation", in which toddlers copy behavior in concert with their play partner as a way to participate in the interaction (Asendorpf, Warkentin, & Baudonnière, 1996; Nielsen, Slaughter, & Dissanayake, 2013).

Research Objectives

As discussed above, current research on children's imitative behavior features debates in theory and ambiguity in empirical evidence. Specifically, little is known about how intrinsic factors of the imitator impact imitation. To fill this gap in research, I propose a dissertation with three major aims:

The first aim is to depict the developmental trajectory of children's imitative behavior. Given previous studies showing a group difference of faithful imitation between toddlers and preschools (McGuigan & Whiten, 2009; McGuigan, et al., 2007; Yu & Kushnir, 2014), in this dissertation I look into how imitative behavior changes in individual children during their third and fourth year (ages of 2 and 3 years).

The second aim is to search for consistencies in individual children's imitative behavior. That is, if a child shows a specific tendency in one imitation task, will he or she show the same tendency in a different imitation task? Will that tendency continue when he or she grows older?

The third aim is to connect individual differences in children's imitative behavior with other aspects of development. In other words, this project explores possible precursors and consequences of different types of imitative behavior.

To achieve the first aim about developmental trajectory, I followed a cohort of children for three visits between the ages of 24 months and 36 months, and measured their imitative behavior. This age range was chosen because previous studies suggest a major increase in fidelity of imitation within this period (McGuigan & Whiten, 2009; McGuigan, et al., 2007; Yu & Kushnir, 2014). It is also a period when children display a mixture of goal-directed and faithful imitation on average, as well as a large amount of behavioral variation across even the same types of imitation tasks (McGuigan & Whiten, 2009; Yu & Kushnir, 2011). Based on previous research, I hypothesize faithful imitation to increase with age.

To separate age effect from possible practice effect (the effect of repeatedly came to the same lab, interacted with the same experimenter, and played with the same toys), I changed all experimental stimuli for each visit, and I also added a second cohort who started to visit the lab at an older age. By comparing the first cohort's later visits and the second cohort's earlier visits, I examined whether there are practice effects.

To achieve the second aim about individual differences in imitation, I tested each child on two different types of imitation tasks during each of their visits. I then analyzed the corrections and patterns among these imitation measurements, in search for consistencies across tasks and ages, as well as factors that can characterize their imitative behavior. Specifically, I look for two factors in children's imitative behavior: imitating the goals of actions or actions that leads to the goal (goal-directed imitation); and imitating the aspects of actions that are irrelevant to achieving the goal, such as the means of actions or unnecessary actions (means-directed imitation). Note that my coding of goal-directed imitation does not imply selectivity (that children imitate nothing else but the goal), and my coding of means-directed imitation does not imply copying everything (that children imitate both the means and the goal). I just coded goal-directed and means-directed imitation as two separate dimensions in children's imitative behavior.

One of the imitation tasks employed here is the puzzle box task. For this project I constructed nine puzzle boxes, all of which have been used in previous imitation studies (Brugger, et al., 2007; Horner & Whiten, 2005; Lyons, et al., 2011; Nielsen, et al., 2012; Yu & Kushnir, 2014). Each of these puzzle boxes is associated with an action sequence that comprises one or two unnecessary actions, then one or two necessary actions, and finally the retrieval of a reward. I measured children's goal-directed imitation by calculating the percentage of necessary actions they imitated, and I measured their means-directed imitation by calculating the percentage of unnecessary actions they imitated.

I also adopted a puppet show task (Carpenter, et al., 2005). In this task, an experimenter moves a puppet to either a cardboard house (House condition) or a same location without a house (No House condition), and he or she does the action in a particular manner (a certain style accompanied by a sound). The presence or absence of the house leads to condition differences in imitation: when a house is present, infants consider putting the puppet into the house as the goal of the action, and thus match the final location; when the house is absent, infants consider the action itself as the goal, and thus match all components of the action. In this dissertation, I measured children's goal-directed imitation by calculating the number of goals they matched (final location in both conditions, plus action manner in the No House condition). I measured their means-directed imitation by calculating the amount of action manner children matched regardless of condition.

These two types of imitation tasks are similar in some ways, but also importantly different. In the puzzle box task, the relevance of actions to the goal is established by physical cause and effect (the necessary actions are *physically* required to retrieve the reward, and the unnecessary actions are not). In the puppet show tasks, the relevance of aspects of actions to the goal is established by the model's intentions (the end-state is the goal in the House condition because the model *intended* to put the puppet in the house; in the absence of a salient end-state, the model's intentions must be inferred to be otherwise). Thus, in my final analysis, I looked to see if individual differences could account for some of the differences in imitative behavior that might transcend immediate contextual influences. To the extent that individual factors contribute to differences in imitative behavior, I expected to see correlations in children's imitative behavior across these two types of tasks.

Finally, to achieve the third aim about connections between imitation and other aspects of development, I measured children's cognitive and social skills via a number of experimental tasks during each visit. I also collected parental report on children's demographic information, general developmental level, language skills, and temperament (see Appendix 1 for a complete list of all measurements). I then analyzed the correlations between children's imitative behavior and these measurements. Based on previous research (Hilbrink, et al., 2013; Wellman, Lopez-Duran, LaBounty, & Hamilton, 2008), I hypothesize to see a correlation between means-directed imitation and children's temperament, as well as a correlation between goal-directed imitation and children's social cognition.

Together, by following children for three visits and collecting data on their imitative and other behavior, this project aims to decode the underlining structure of children's imitative behavior, to plot how it changes with age, to associate it with individual differences in other aspects, and to ultimately shed light on why a particular child uses a particular imitation strategy in a particular scenario.

CHAPTER 2

METHOD

Design

This study employed a sequential design. Two cohorts of children visited the lab for three visits (Table 1). For each visit, all children were tested for the same tasks in the same order. The imitation tasks were interspersed throughout the testing session to reduce priming effects. To diminish possible practice effects, I either changed the stimuli, or changed its color and decoration for all tasks during children's second and third visits. For the Puzzle Box Task and "There" vs. "Whoops" Task, three apparatuses were created for each set, and children were tested on one of these three apparatuses for each visit. The order of apparatuses used for each visit was counterbalanced across children; so that the

Table 1. Children's age when they come to the lab for the three visits.

	Visit 1	Visit 2	Visit 3
Cohort 1 (*n* = 32)	24 mo	30 mo	36 mo
Cohort 2 (*n* = 16)	30 mo	36 mo	42 mo

differences observed between visits would not confounded by the differences between apparatuses. For the Puppet Show Task, Grass/Snow Task, Theory-of-Mind Scale, Word Learning Task, and Artifact Function Task, I changed stimuli for children's each visit, but did not counterbalance the order of stimuli across children. This is because for these tasks different sets of stimuli were conceptually similar, and were unlikely to alter children's responses. For the Corsi Block-Tapping Task and Sorting Task, I changed the color of the stimuli for children's each visit. Until the point when this dissertation is written, all children have completed their first and second visits, and data collection for the third visit is still ongoing.

Participants

Participants were 32 children of Cohort 1 who first visited the lab at 24 months of age (15 boys, mean age = 24 mo, range = 23-25 mo), and 16 children of Cohort 2 who first visited the lab at 30 months of age (6 boys, mean age = 30 mo, range = 29-32 mo). All participants were recruited from a small university town in upstate NY. One additional child was tested but excluded from analysis because she did not understand English. According to parental report, 79% of the included children are Caucasian, 98% of their primary caregivers have college diploma or higher, and 85% of their families have an annual household income > $50,000.[1] Children received stickers, gifts and/or T-shirts for each visit, and their parents received $10 for each visit. After each visit, parents also received a report on the questionnaires they filled out, as well as a DVD recording the experimental session.

Thirty-seven of these 48 children (77%) completed all three visits, including 28 children from Cohort 1 and 9 children from Cohort 2. Among the 11 families who missed at least one visit, six moved away during the course of the experiment; one was too busy to schedule appointments; one could not come because the child suffered chronicle illness; and three did not respond to invitation for later visits; None of the demographic variable (gender, race, social economic status) differed between children who came back for the second visit and children who did not (*p*s > .2).

Experimental Measurements

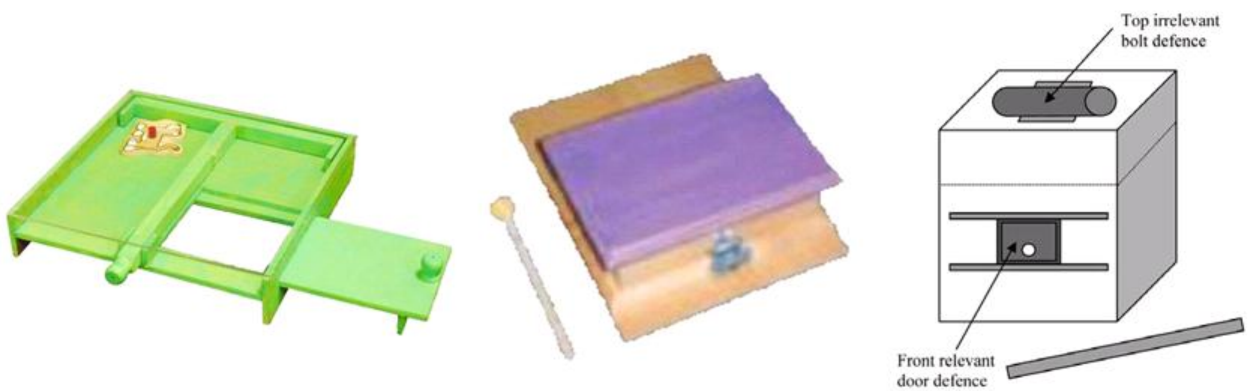
The same male experimenter (E) and one of eight assistants conducted all experiments for all visits. Children first warmed up with E and assistant in a laboratory corridor filled with toys. After children felt comfortable, they were introduced into a playroom where all testing take place. E sat facing children across a table for all tasks

[1] My sample mainly consisted of White children and children born from highly educated parents. Therefore, further research is needed to verify if my results can be generalized to children from other cultures and socioeconomic strata. However, it is heartening to see recent cross-cultural work confirm some of the imitation results from primarily Western samples (Callaghan et al., 2011; Nielsen & Tomaselli, 2010), which suggests the fidelity and goal-directedness in children's imitation may be universal to some extent.

except for the third set of puzzle box task, in which both E and children played on the floor away from the table. The accompanying parents sat either next to children in a separate chair, or sat outside the room. If parents sat next to children they were instructed to remain neutral. All experiments were videotaped.

Puzzle Box Task

The puzzle box task was used to measure imitation in a context with an instrumental goal (a reward). I built three sets of puzzle boxes, with three boxes in each set (examples see Figure 1). Set 1 (the Flower Box, the Ramp, and the Rake) mimicked those originally used in Brugger and colleague's study (2007), and was recently used in Yu & Kushnir (2014). Set 2 (the Blue Box, the Switch Box and the Artificial Fruit) mimicked those used in Nielson and colleague's study (2012). Set 3 comprised a replicate



"Rake" (Brugger, et al., 2007) | "Blue Box" (Nielsen, et al., 2012) | "Clear Box" (Horner & Whiten, 2005)

Figure 1. Examples of the puzzle boxes used in the puzzle box task.

Table 2. Descriptions for the nine puzzle boxes used in the puzzle box task.

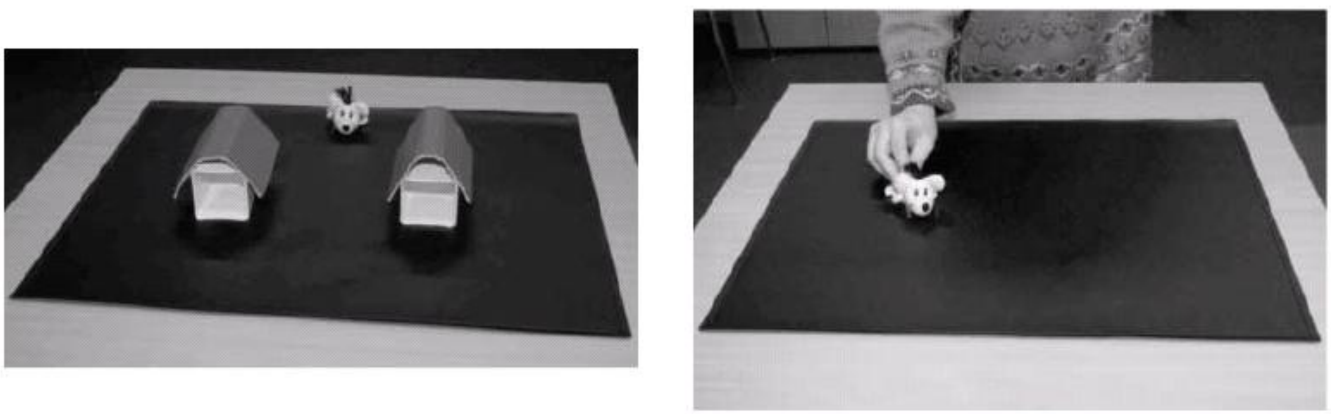
	Set	First set			Second set			Third set		
	Original study	Brugger et al., 2007; Yu & Kushnir, 2014			Nielson et al., 2012			Horner & Whiten, 2005	Lyons et al., 2011	
Symbol	Box	Ramp (purple)	Rake (green)	Flowerbox (orange)	Blue Box	Switch Box	Artificial Fruit	Clear box	Monkey box	Prize box
U1	First unnecessary action	Remove barrier (hand)	Cover hole (hand)	Remove Velcro latch (hand)	Place red stick on top of box and wipe around in a circular motion three times (tool)	Tap mallet on top of box three times (tool)	Wipe blue stick along box from back to front three times (tool)	Push the bolt (tool)	Push the bolt (tool)	Swing arm (hand)
U2	Second unnecessary action							Tap (tool)	Tap (tool)	
N1	First necessary action	Push the piece with the pusher (hand)	Pull out a T-shaped paddle (hand)	Pull open the lid (hand)	Hold stick on top of knob, push down, and in so doing open front of box (tool)	Using mallet, push switch from left to right to open box (tool)	Using blue stick, push out dowels toward front until they fall onto top of table (tool)	Open door (hand)	Open door (hand)	Open door (hand)
N2	Second necessary action							Insert stick (tool)	Insert stick (tool)	Insert stick (tool)
C	Reward	puzzle piece			bell toy	castanet	toy monkey	puzzle piece	ball	ball
	Characteristics	Unnecessary actions are instrumental, unnecessary actions and necessary actions applied on connected parts of the box (same surface), small simple boxes			Unnecessary actions are ritual, unnecessary actions and necessary actions applied on separate parts of the box, necessary actions demonstrated with tool (but can use hand), small simple boxes			Unnecessary actions are instrumental, unnecessary actions and necessary actions applied on separate parts of the box, unnecessary actions demonstrated with tool (expect for Prize Box), large complex boxes		

of the Clear Box (Horner & Whiten, 2005), as well as replicates of the Monkey Box and the Prize Box (Lyons, et al., 2011). Each of these puzzle boxes contained a reward in them, and was associated with an action sequence to retrieve the reward. Each of these action sequences comprised one or two actions that are unnecessary for retrieving the reward, followed by one or two actions that are necessary, and finally the retrieval of the reward (Table 2). The unnecessary and necessary actions were demonstrated either with hand, or with a tool. Notably, the puzzle boxes in the third set were mostly used for preschoolers in previous studies, and one study which used them with 2-year-olds showed only 17% of children imitated the unnecessary actions (McGuigan & Whiten, 2009). I expect the same to happen in my study.

For each visit, children played with three puzzle boxes, one from each set. These three trials were interspersed throughout the testing period. For each trial, E presented the puzzle box, said “Watch me”, and demonstrated the action sequence in a slow, deliberate fashion. At the end he took out the reward and showed it to children. He then removed the box and the reward from children’s view, and placed the reward back inside. He returned the box, saying “Now your turn”. Children played with the box until they retrieved the reward, or until they lost interest in the box. The videos were coded along three independent dimensions: how many necessary actions children imitated, how many unnecessary actions they imitated, and whether they retrieved the reward. In cases where children imitated the actions, I further differentiated whether they used a same means or different means than E (e.g., whether they used hand or used a tool when E demonstrated the action with a tool). Videos from 20% of all children were coded by a second coder.

Puppet Show Task

The puppet show task measured imitation in a context with no external reward. This task was administrated and coded in the same way as in the original research (Carpenter, et al., 2005), the only difference being I reduced the number of trials from eight to four. As shown in Figure 2, in each trial children were presented with one of two mats on the table: an empty mat (No House condition) or a mat with two cardboard houses on the centers of the mat's left half and right half (House condition). In both



House condition (2 trials) No House condition (2 trials)

Figure 2. Setup of the puppet show task.

Left: the start state in the House condition; Right: the end state in the No House condition.

conditions, E moved a puppet (e.g., a mouse) towards the center of the mat's left half or right half. In the House condition the final location was inside one of the houses. In the No House condition the final location was the same spot on the mat, but not in a house. The final location was to the left side of the mat for half the trials in each condition, and was to the right side for the other half. E used one of two action styles when moving the puppet: he either made the puppet jump on the mat several times ("hopping"), or slid the puppet without breaking contact with the mat ("sliding"). E always made a repeated short sound (e.g., "bebebe…") to accompany the hopping style, and he made a long sound (e.g., "beeeee…") to accompany the sliding style. The puppet was made to hop in half of the trials in each condition, and to slide in the other half. The order of condition (House vs. No House), style (hopping vs. sliding) and final location (left vs. right) were counterbalanced between children.

In each of the four trials, E first elicited children's attention by calling their names. He said "Watch me", and moved the puppet to one of the final locations. E then picked up the puppet and placed it in front of children. E told children, "Your turn", and waited children's response till he or she stopped handling the puppet. The videos were coded for whether children matched E on the style, sound effect and final location. Videos from 20% of all children were coded by a second coder.

Corsi Block-Tapping Task

The Corsi block-tapping task (Kessels, van Zandvoort, Postma, Kappelle, & de Haan, 2000) was used to measure children's working memory, which is one component of their executive function. The task was administrated according to the original study. E presented children a board with eight colorful blocks attached to it. E first tapped one block, and asked the child to follow. He then repeated with another block. If children followed at least one of these correctly, the next two trials of a sequence of an increased length were administered (i.e., two 2-block sequences, then two 3-block sequences, etc.). Two trials were given per block sequence of the same length. The test was terminated if children failed to reproduce two sequences of equal length. The Total Score was computed and used as an outcome variable, which was the sum of the sequence length for all successfully completed sequences.

Grass/Snow Task

The Stroop-like Grass/Snow task (Carlson & Moses, 2001) was used to measure children's inhibition of prominent responses, which is another component of their executive function. After verifying that children could name the colors of grass and snow, E introduced a large board with a white card and a green card attached to the upper-left and the upper-right corners of it. Children were instructed to point to the white card when E said "grass" and to the green card when E said "snow". Two (or more) practice trials and six test trials followed in the same fixed random order. The final score is the number of children’s correct answers. Three variations of this task have been built, including Grass/Snow, Day/Night, and Fire/Water.

Sorting Task

The sorting task was used to measure children’s ability to learn categorization from a model. Stimuli used in this task are cylinder-shaped barrels that vary in both a superficial property (color) and a hidden property (whether it makes a noise when shaken). Each child completed three trials, which increased in difficulty. The first trial measured if children can learn to sort by a superficial property: E sorted four quiet barrels into two boxes according to color. Children were then given the same barrels to sort. The second trial measured if children can learn to sort by a hidden property: E sorted four barrels of the same color; two of them made noise and the other two were quiet when shaken. E shook the barrels before sorting them into the boxes. Children were then given the same barrels to sort. The third trial measured if children can refer to E’s social cues when the end state of sorting is ambiguous. In this trial E presented two noisy barrels of one color, and two quiet barrels of another color. He shook each barrel, and then sorted them into two boxes according to both color and sound. Children were then asked to sort a different set of four barrels, in which color and sound were crossed. If they understood why E purposefully shook objects before sorting them, they should infer that he sorted by sound, and therefore they should sort their own pile by sound. I recorded whether children sorted by color, sorted by sound, and sorted in other ways in these three trials, and used the number of their correct responses (sort by color in the first trial and sort by sound in the later two trials) as an indicator of children's preparedness to learn category knowledge.

Theory-of-Mind Scale

The Theory-of-Mind scale (Wellman & Liu, 2004) was used to examine children's social cognition. Given the age range of these children, I used the first three items from the scale: the Diverse Desire task, the Diverse Belief task and the Knowledge Access task. Children's answers in these tasks represent whether they understand that different people have different mental states (desires, believes, and knowledge states), and that people act according to their own mental state. The Contents False Belief and the Real-Apparent Emotion tasks were not administrated, because children under 36 months of age are unlikely to pass them (Wellman, Cross, & Watson, 2001). Since no order effects was found for these tasks (Wellman & Liu, 2004), the tasks were always administrated from the easiest (the Diverse Desire task) to the hardest (the Knowledge Access task.), just as in the original study. I prepared three sets of stories so that children heard different stories for each visit.

"There" vs. "Whoops" Task

The "There" vs. "Whoops" task (Carpenter, et al., 1998) was administrated to test children's understanding of the demonstrator's intentions carried out through verbal cues. I closely matched the material and procedure to the original study. I prepared six apparatuses that have two actions and one effect associated with each. Children completed two trials during each visit. E sequentially modeled two actions, and produced the effect. One of the actions was verbally marked with “There” and one was verbally marked with “Whoops”. The effect appeared to be associated with the two actions, but was actually controlled by E. If children are sensitive towards E’s intentions, they should selectively copy the intentional action accompanied by “There”, but not the accidental action accompanied by “Whoops”. I recorded whether children produced the “There” action as a measurement for their understanding of other people’s intentions. Which action caused the effect and which action E performed first was counterbalanced both within a child’s three visits, and between children.

Word Learning Task

The word learning task examined children’s understanding of conventionality—whether they understand word labels are shared between individuals who speak the same language. Each child completed the different-speaker-word condition in Henderson and Graham (2005)’s Experiment 1, and the different-speaker-preference condition in their Experiment 2. The order of conditions was counterbalanced. In the different-speaker-word condition, E first introduced children to two objects, one labeled with a pseudo word (e.g., “Mido”) and one not labeled. Then E left the room and the assistant came in. The assistant asked children for “Mido” for both the original set of objects, and a new set of objects with the same shape but different color. If children gave the assistant the

“Mido” introduced by E, it is taken as evidence that they understand labels are shared between individuals. E then returned and asked children for another label (e.g., “Toma”), to test whether they understand that word-label correspondence is mutually exclusive. The different-speaker-preference served as a control, to show that children did not just give the assistant anything labeled by E. This condition is identical as the different-speaker-word condition, except that E introduced his preference (“I like this one.”) instead of a label. If children understand that preferences are personal and not shared across individuals, they should choose by chance when the assistant asked them which one she likes.

Artifact Function Task

The artifact function task examined the extent to which children assume conventionality in the use of tools—that artifacts are “for” particular purposes. Following the design of previous studies (Casler & Kelemen, 2005, 2007), children were presented with two novel tools that are physically equivalent but perceptually distinct. One tool was assigned an implicit function through a short demonstration. The dependent measurements are whether children returned to the demonstrated tool when asked to repeat the task, and whether they preferred the other tool for a different task (i.e., assume each tool is used exclusively for one task).

Sharing Task

The sharing task (Chernyak & Kushnir, 2013) was used to measure children's prosocial behavior. In the end of the experiment E give children five stickers as an appreciation for their participation. E then presented children with a puppet dog and two boxes. He told children that "doggie" is feeling sad and will feel better by receiving some stickers, but it is also fine for children to keep their stickers. He then instructed children to put the stickers either in doggie's box or in their own box. The number of stickers shared was used as a measurement for children's prosocial behavior.

Parental Reports

For each visit parents filled out four questionnaires listed below. They either completed these questionnaires in the lab, or took them home to finish and mailed back to the experimenter. I requested these questionnaires to be filled out by someone who is familiar with the child's daily activities.

Demographic Variables

During the first visit, parents filled out a demographic questionnaire asking for the following information: the child's birth date, gender and race, whether the child was born preterm or full term, whether the child had been diagnosed with any developmental disorders, parents' education level, annual household income, number of older and younger siblings the child has, and the length and frequency of the child's day care/preschool experience. In the subsequent visits, parents were asked to read through the questionnaire again and modify any information that had changed since their last visit.

General Developmental Level

Children's general developmental level was measured through parental reports of the General Development Scale of Child Development Inventory (Ireton, 1992). This scale contains 70 items, which asks for milestone achievements in children's development. The domains measured by this inventory includes social skills, self help, gross motor skills, fine motor skills, expressive language, language comprehension, and comprehension of letters and numbers.

Language

Productive language skill was measured by the MacArthur Communicative Development Inventories (Fenson et al., 2000). Based on the suitable age range of the questionnaires, short form CDI-II Form B was filled out for 24-months and 30-months-old children; CDI-III was filled out for 30-months, 36-months and 42-months-old children. Both questionnaires contain 100 words, and parents were asked to report if children can produce these words. When children came at 30 months, parents filled out both CDI-II and CDI-III (since both questionnaires are suitable for that age). By comparing CDI-II and CDI-III scores for the same child at the same age, I established an algorithm to compute one continuous language score from the two questionnaires (details see Appendix 2).

Temperament

Children's temperament was measured by the Early Childhood Behavior Questionnaire (Putnam, Gartstein, & Rothbart, 2006) and the Child's Behavior Questionnaire (Rothbart, Ahadi, Hershey, & Fisher, 2001). Based on the suitable age range of the questionnaires, ECBQ was filled out for 24-months, 30-months and 36-months-old children; CBQ was filled out for 36-months and 42-months-old children. I used the very short version of both questionnaires. Each questionnaire contains 36 items on three subscales: Surgency/Extraversion, Negative Affectivity, and Effortful Control. Again, I established an algorithm to compute one continuous score for each subscale of the two questionnaires (details see Appendix 2).

Data Analysis

All data were coded and entered into IBM SPSS Statistics 20. The coding schemes for all measurements are listed in Appendix 1. Data analysis was conducted with SPSS, R, and Excel. I used t-tests, ANOVAs and mixed model regression analyses to analyze developmental changes. I used correlations, mixed model regression analyses, and canonical correlation analysis to analyze individual differences. A detailed description of the mixed model regression analysis is attached in Appendix 3.

CHAPTER 3

RESULTS

In this chapter I first report developmental changes observed in children's three visits, then I report individual differences observed within each imitation task, between different imitation tasks, and between imitation tasks and other measurements.

Developmental Changes

In this section I report developmental changes in children's behavior in the imitation tasks and other tasks/measurements. All developmental changes were assessed using mixed models (details see Appendix 3). In these models the covariance among each child's different visits was accounted for by including participant number as a predictor with random effect; and practice effects were controlled for by including the number of visit as a predictor with fixed effect. The focal predictor was age, and it was dummy-coded to allow non-linear age trends. The coefficients for the three dummy codes represent the age differences between 24 and 30, 30 and 36, and 36 and 42 months of age.

Puzzle Box Task

All children participated in all three trials of the puzzle box task during all three visits. Boys and girls did not differ on any of the outcome measurements (ps > .13). Inter-rater reliability was high for all outcome measurements (Cohen's Kappas > 0.8 for reward retrieval, imitation of goal-relevant actions, and imitation of unnecessary actions).

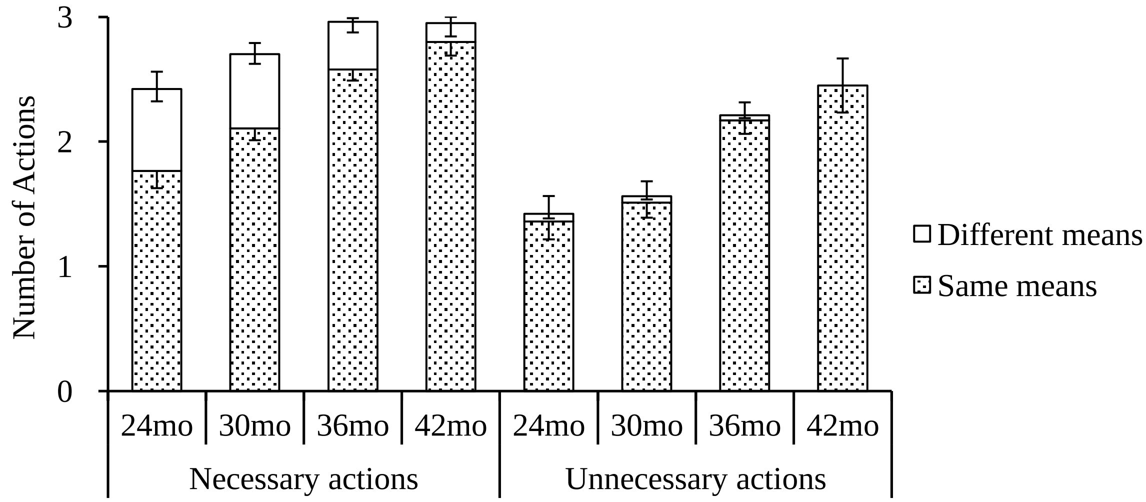


Figure 3. Number of actions children imitated in the puzzle box tasks.

Note. For each puzzle box children received a score between 0 and 1 for the number of necessary and unnecessary actions they imitated (if the puzzle box contains two necessary or unnecessary actions, the percentage of actions imitated was used). The total possible score is 3. I separated the actions for which children imitated with the same means as the experimenter (e.g., using tool when the experimenter is using tool) or different means as the experimenter (e.g., using hand when the experimenter is using tool). The three error bars from top to bottom (upwards, downwards and downwards) denotes SEs of total number of actions imitated, actions imitated with different means, and actions imitated with the same means.

For the number of rewards children retrieved from the puzzle boxes, there was a significant increase between 30 and 36 months of age, t (133.1) = 2.03, p = .05. For the total number of unnecessary actions imitated, there was also a significant increase between 30 and 36 months of age, t (121) = 2.32, p = .02. The result was the same when only imitation with the same means is considered, t (120.5) = 2.36, p = .02. For the total number of necessary actions imitated, age was not a significant predictor, and none of the differences between two adjacent age groups were significant (ps > .12). However, when only imitation with the same means is considered, there was a significant increase of necessary actions children imitated between 30 and 36 months of age, t (103.6) = 3.21, p = .002. These results showed that for the puzzle box task, although both goal-directed and means-directed imitation increased from 24 to 42 months of age, the most significant increase was in means-directed imitation between 30 and 36 months of age.

Puppet Show Task

Data from three children's four visits (2 at 30 month, 1 at 36 month, 1 at 42 month, 3% of total visits) were dropped from the analysis because during these visits children were too distracted or fuzzy to participate in this task. Inter-rater reliability was high for all outcome measurements (Cohen's Kappa = 0.91, 0.97, 0.88 for style, sound, and location). No dependent measurements differed based on the order the experimenter administrated the four trials (*p*s > .3).

I replicated the results of the original study (Carpenter, et al., 2005) in showing different imitative behavior between conditions (Figure 4 & 5). Results from mixed models showed that overall children were more likely to match the final location in the House condition than in the No House condition, t (195.5) = 6.36, p < .001. On the other hand, they were more likely to match the style of the experimenter in the No House condition than in the House condition, t (192.4) = 5.75, p < .001.

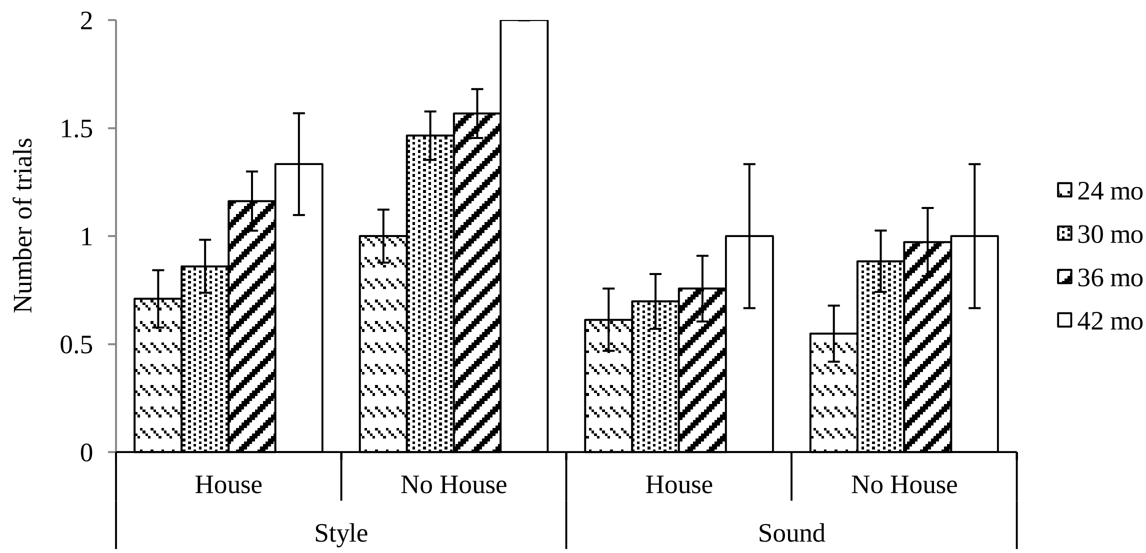


Figure 4. Number of trials in which children matched style and sound of the experimenter's actions in the puppet show task.

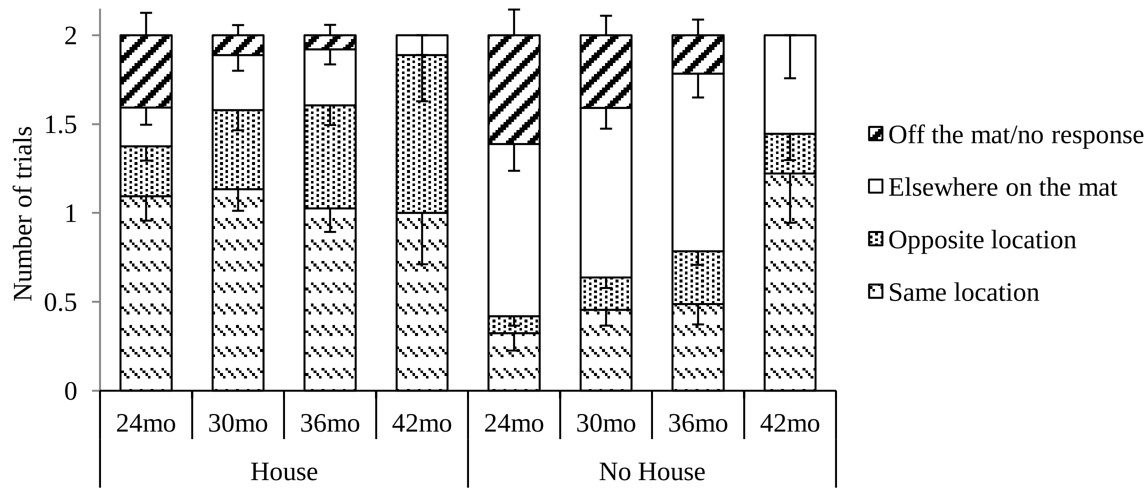


Figure 5. How children matched the experimenter's final location in the puppet show task.

Note. "Same location" means children put the puppet into the same house as the experimenter did (House condition), or to its corresponding location on the mat (No House condition); "Opposite location" means children put the puppet into the house on the opposite side of the mat (House condition), or to its corresponding location on the mat (No House condition).

For the developmental changes, before practice effects were controlled for, age was a significant predictor for matching style, F (3, 216.6) = 10.3, $p < .001$, and the differences between each two age pairs were significant, ps < .05. However, after I added the number of visit into the model to control for practice effects, neither age nor the number of visit predicted any outcome measurements, ps > .12. When separating the two conditions, age was a significant predictor only for matching location in the No House condition, F (3, 73.5) = 3.99, p = .01; major increase happened between 36 and 42 months of age, t (114.0) = 3.41, p = .001.

Other Measurements

Table 3 reported developmental differences in other measurements. Whereas significant improvements in parental-reported general developmental level and language skills occurred throughout the three age periods (24-30 mo, 30-36mo, 36-42mo), the changes in children's performance in most experiments was significant in only one or two of these age periods. Executive functions scores (working memory and inhibition) and Theory-of-Mind scores increased significantly between 30-36 mo and 36-42 mo. Categorization scores increased significantly between 24-30 mo and 30-36 mo. The scores of normative reasoning of labels and artifact functions increased significantly only between 30-36 mo, which coincides with the age range in which children performed significantly more means-directed imitation in the puzzle box task.

Table 3. Parental reports and children's performance in experimental tasks other than the imitation tasks, listed by age.

Task/Questionnaire	Measurement	Score Range	24 months		30 months		36 months		42 months	
			Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Demographic Questionnaire	Number of siblings	⩾0	0.94	1.13	0.96	0.99	1.10	1.07	0.70	0.48
	Daycare/preschool experience[1]	⩾0	5.5	9.1	**10.5***	13.1	**13.9***	15.1	**31.2*****	16.7
CDI	General developmental level	0-70	35.1	6.9	**45.8*****	6.7	**53.5*****	7.8	**60.1****	4.6
McArthur CDI II/III[2]	Language skill	—	0.17	0.51	**0.72*****	0.51	**1.17****	0.55	**1.46***	0.34
ECBQ/CBQ[2]	Surgency/extraversion	—	5.28	0.57	5.39	0.60	5.59	0.58	5.44	0.78
	Negative affectivity	—	2.84	0.65	2.84	0.65	2.94	0.51	3.34	0.67
	Effortful control	—	4.78	0.68	5.07	0.65	5.18	0.59	5.19	0.62
Corsi Block-Tapping Task	Working memory	⩾0	1.11	1.71	2.19	2.20	**4.79****	3.21	**6.60**†	2.72
Grass/Snow Task	Inhibition	0-6	1.17	1.06	1.43	1.94	**2.36***	1.97	**4.10****	2.13
Sorting Task	Categorization	0-3	0.15	0.36	**1.14*****	0.81	**1.81*****	0.82	2.10	0.88
Theory-of-Mind Scale	Theory-of-Mind	0-3	0.83	0.78	1.10	0.77	**1.51**†	0.83	**2.10***	0.57
There vs. Whoops Task	Imitation of intentional action	0-2	0.83	0.89	1.28	0.60	1.13	0.57	1.10	0.57
Word Learning Task	Normative reasoning of labels	0-3	2.01	1.20	2.11	0.99	**2.54***	0.72	2.70	0.67
	Normative reasoning of preference	0-2	0.71	0.76	0.95	0.85	1.17	0.77	1.11	0.78
Artifact Function Task	Normative reasoning of functions	0-2	0.88	0.61	0.86	0.63	**1.23****	0.67	1.20	0.79
Sharing Task	Prosocial behavior	0-5	2.79	2.15	2.24	2.02	1.38	1.51	1.70	1.16

Note. [1] The attendence-adjusted number of months children spent in daycare or preschool (details see Appendix 1).

[2] I used algorithms to convert scores from multiple questionnaires into single language/temperament scores (details see Appendix 2). Due to the conversion, the score ranges are different from that in the original questionnaires.

$^{\dagger, *, **, ***}$: These denote significant or marginal differences between the measurement in the age group which this cell represents, and the previous age group. For example, * in the cell "Daycare/preschool experience, 30 months" means

30-months old children have significantly more daycare/preschool experience than 24-months-olds. The statistics being used here is the estimates of coefficients in the mixed model (Appendix 3).

†: $p < .1$; * $p < .05$; ** $p < .01$; *** $p < .001$.

Individual Differences

In this section I report individual differences observed within each imitation task, between different imitation tasks, and between imitation tasks and other measurements.

Puzzle Box Task

Children showed consistency in their imitative behavior across three sets of puzzle boxes. Mixed model showed that after controlling for the fixed effect of age and the random effect of participant, whether children imitated the unnecessary action of Set 1 in a certain visit correlated with whether they imitated the unnecessary action of Set 2 in that visit, t (122) = 2.27, p = .03. Similar correlations were found in the imitation of necessary actions between Set 1 and Set 2, t (118.6) = 3.42, p = .001, and between Set 2 and Set 3, t (111.4) = 2.17, p = .03.

In terms of consistency of imitative behavior between visits, the number of necessary actions children imitated in the puzzle box task correlated between their second and third visits, r (36) = 0.38, p = .02. When the two cohorts of children were separated, in the younger cohort children's imitation of necessary actions correlated between their visits at 30 and 36 months of age. However no such correlation was observed in the older cohort.

Puppet Show Task

To investigate individual differences among different measurements in the puppet show task, I first explored the correlation matrix of each age group. Here I separated data by age group because a) within each age group all samples are independent, thus meeting the assumption of independent sampling for correlation analysis; and b) it allows the structure of variables to change with age. The group of 42-months-olds was small (*N* = 10)

Table 4. Intercorrelations among six outcome measurements in the puppet show task for 24-months-old children.

		Style		Sound		Location	
		House	No House	House	No House	House	No House
Style	House	—	.198	**.435***	**.443***	.165	.159
	No House		—	**.364***	**.675*****	.192	.180
Sound	House			—	**.665*****	.272	.067
	No House				—	.170	.129
Location	House					—	.138
	No House						—

Note. *N* = 32. $^{*}p < .05$; $^{***}p < .001$

Table 5. Intercorrelations among six outcome measurements in the puppet show task for 30-months-old children.

		Style		Sound		Location	
		House	No House	House	No House	House	No House
Style	House	—	.193	**.515*****	-.213	.126	.225
	No House		—	.080	**.394****	.027	.190
Sound	House			—	**.292**†	.042	.048
	No House				—	-.013	.216
Location	House					—	.077
	No House						—

Note. N = 45. $^{\dagger}p < .10$; $^{**}p < .01$; $^{***}p < .001$

and homogeneous in their performance, so it was not included in the correlation analysis. Results from the remaining three age groups (Table 4-6) showed that for all three age groups, the number of style and sound children matched correlated with each other and correlated across two conditions. In addition, for 36-months-old children, the number of location they matched in the House condition correlated with the number of style they matched in the No House condition. These results confirmed my hypothesis of two components in children's imitative behavior: means-directed imitation which is represented by copying style and sound across conditions; and goal-directed imitation which is represented by copying final location in the House condition and copying all aspects of the action in the No House condition.

Table 6. Intercorrelations among six outcome measurements in the puppet show task for 36-months-old children.

		Style		Sound		Location	
		House	No House	House	No House	House	No House
Style	House	—	**.561*****	**.498*****	**.284**†	.034	.227
	No House		—	**.528*****	.192	**.296**†	.182
Sound	House			—	**.839*****	-.026	.041
	No House				—	-.178	-.025
Location	House					—	.105
	No House						—

Note. N = 38. $^{\dagger}p < .10$; $^{***}p < .001$

Correlations between Different Types of Imitation Tasks

I used a canonical correlation analysis to explore the covariance between the measurements in the puzzle box task and the puppet show task. The analysis was performed using the CCA package in *R*. Two measurements from the puzzle box task were entered as the first set of variables; six measurements from the puppet show task were entered as the second set of variables (Table 7). Results showed two canonical dimensions: dimension 1 had a canonical correlation of 0.40 between the sets of variables, while for dimension 2 the canonical correlation was much lower at 0.21. Table 7 presents the standardized canonical coefficients for the two dimensions across both sets of variables. The first dimension showed high loadings (> .3) on imitation of both unnecessary and necessary actions in the puzzle box task, and matching style (both conditions) and sound (No House condition) in the puppet show task. This dimension roughly corresponded to the factor of means-directed imitation. The second dimension showed high loadings on imitation of necessary actions in the puzzle box task, and matching location (House condition) and style (No House condition) in the puppet show task. This dimension roughly corresponded to the factor of goal-directed imitation.

Table 7. Standardized canonical coefficients from the canonical correlation analysis.

		Dimension	
		1	2
Puzzle box task	Unnecessary	**.606**	-.848
	Necessary	**.643**	**.821**
Puppet show task	House, style	**.397**	-.436
	No House, style	**.430**	**.768**
	House, sound	.077	-.268
	No House, sound	**.421**	-.592
	House, location	.143	**.328**
	No House, location	.259	.209

Correlations between Imitation Behavior and Other Measurements

Following my initial theoretical framework, I calculated scores for goal-directed imitation, means-directed imitation, and total imitation for each child's each visit. The score for goal-directed imitation was the sum of the number of necessary actions children imitated in the puzzle box task, the number of final locations they matched in the House condition of the puppet show task, and the number of style, sound and final location they matched in the No House condition. The score for means-directed imitation was the sum of the number of unnecessary actions children imitated in the puzzle box task, and the number of style and sound they imitated across two conditions in the puppet show task. Finally, the total imitation score was the sum of all eight outcome measurements from the imitation tasks (two from puzzle box task and six from puppet show task).

In this session I report correlations between these two factors and other children's other measurements. Again, I separated data by age group to meet the independent sampling assumption and to allow age-dependent correlations to emerge. I dropped the 42-months-olds group as the group was small (N = 10) and homogenous in their imitative behavior.

Results (Table 8-10) showed that patterns of correlations were very different for children of different ages. For 2-year-olds (24 mo and 30 mo), means-directed imitation and total imitation were not significant predictors of any outcome measurements. On the other hand, goal-directed imitation predicted Theory-of-Mind and prosocial behavior

Table 8. Concurrent correlations between imitative behavior and other measurements at 24 months, $N = 32$.

	Zero-order correlation			Partial correlation		
	Goal-directed imitation	Means-directed imitation	Total imitation	Goal-directed imitation	Means-directed imitation	Total imitation
Age	-.181	-.034	.053	—	—	—
General developmental level	.251	.197	.267	—	—	—
Language skill	-.075	.098	-.022	—	—	—
Number of siblings	-.127	-.295	-.221	-.261	-.330†	-.360†
Daycare/preschool experience	-.072	-.199	-.141	-.187	-.250	-.219
Surgency/extraversion	.199	.243	.280	.113	.227	.213
Negative affectivity	.017	-.289	-.002	-.028	-.295	-.044
Effortful control	-.105	-.007	-.084	-.067	-.028	-.090
Working memory	-.144	-.015	-.040	-.149	-.091	-.068
Inhibition	-.112	-.050	-.084	-.167	-.087	-.141
Categorization	-.086	-.065	-.126	-.124	-.097	-.163
Theory-of-Mind	.214	-.003	.152	**.506***	.133	.384
Imitation of intentional action	-.165	-.035	-.065	-.198	-.049	-.106
Normative reasoning of labels	-.095	.233	.050	-.277	.167	-.094
Normative reasoning of preferences	-.014	-.112	-.023	-.165	-.165	-.175
Normative reasoning of artifacts	.133	.139	.139	.101	.104	.122
Prosocial behavior	**.474***	.277	.305	**.561***	.348†	.370†

Note. Numbers in this table denotes correlation coefficients (rs). Partial correlations represent correlations after controlling for age, general developmental level, and language skills.

$^{\dagger}p < .05$; $^{*}p < .05$; $^{**}p < .01$

Table 9. Concurrent correlations between imitative behavior and other measurements at 30 months, $N = 47$.

	Zero-order correlation			Partial correlation		
	Goal-directed imitation	Means-directed imitation	Total imitation	Goal-directed imitation	Means-directed imitation	Total imitation
Age	.010	-.067	-.007	—	—	—
General developmental level	**.379***	.185	.185	—	—	—
Language skill	.098	.064	.073	—	—	—
Number of siblings	-.063	-.055	-.110	-.130	-.084	-.143
Daycare/preschool experience	.119	.185	.131	.089	.159	.116
Surgency/extraversion	-.043	.255	.172	-.099	.257†	.168
Negative affectivity	.201	-.089	-.118	.163	-.141	-.160
Effortful control	.007	-.130	-.092	-.051	-.156	-.130
Working memory	.243	.021	.107	.207	-.003	.079
Inhibition	-.056	.174	-.024	-.106	-.172	-.039
Categorization	.372	.208	.280	-.278†	-.143	.235
Theory-of-Mind	.154	-.053	.010	.088	-.102	-.027
Imitation of intentional action	.204	.029	.120	-.297	.069	.157
Normative reasoning of labels	.163	.039	.072	-.034	-.049	-.021
Normative reasoning of preferences	.285†	.152	.115	.342	.146	.130
Normative reasoning of artifacts	.233	.179	.231	.164	.139	.201
Prosocial behavior	.176	-.044	-.130	.105	-.109	-.181

Note. Numbers in this table denotes correlation coefficients (*r*s). Partial correlations represent correlations after controlling for age, general developmental level, and language skills.

† $p < .05$; * $p < .05$; ** $p < .01$

Table 10. Concurrent correlations between imitative behavior and other measurements at 36 months, $N = 39$.

	Zero-order correlation			Partial correlation		
	Goal-directed imitation	Means-directed imitation	Total imitation	Goal-directed imitation	Means-directed imitation	Total imitation
Age	.110	.069	-.149	—	—	—
General developmental level	**.418****	.249	.150	—	—	—
Language skill	**.558*****	**.371***	**.381***	—	—	—
Number of siblings	.145	.072	-.002	.021	-.013	-.113
Daycare/preschool experience	.387	.163	.175	**.436***	.162	.224
Surgency/extraversion	-.101	-.089	-.193	.059	.009	-.096
Negative affectivity	-.058	-.062	-.220	.045	.006	-.150
Effortful control	-.042	-.228	-.203	-.313†	**-.414***	**-.394***
Working memory	.244	**.524****	**.410***	.181	**.528****	**.491****
Inhibition	.006	.033	-.020	.098	.087	.021
Categorization	.200	**.335***	.287†	-.313†	**.403***	**.388***
Theory-of-Mind	.074	.136	.088	-.028	.092	.087
Imitation of intentional action	-.108	-.065	-.010	-.143	-.073	-.034
Normative reasoning of labels	.190	.106	.008	.159	.070	-.047
Normative reasoning of preferences	.179	.135	.292	.014	.034	.235
Normative reasoning of artifacts	.163	**.309***	.091	.094	**.316***	.235
Prosocial behavior	-.024	.223	.169	-.171	.168	.117

Note. Numbers in this table denotes correlation coefficients (rs). Partial correlations represent correlations after controlling for age, general developmental level, and language skills.

† $p < .05$; * $p < .05$; ** $p < .01$

(24mo) as well as general developmental level (30mo). This suggests that the goal-directed component of imitation may be more closely associated with overall development in toddlerhood, and in particular with the development of social cognition. On the other hand, for 36 months olds means-directed imitation was significantly correlated with language, effortful control, working memory, categorization, and normative reasoning of artifact functions. This suggests an increasingly stronger association between means-directed component of imitation and other aspects of development, especially with executive function and normative reasoning. Goal-directed imitation was still significantly correlated with general developmental level, language skills and daycare/preschool experience, but no longer predicted children's performance in specific experimental tasks. Connecting this with the significant increase in means-directed imitation between 30-36 months of age, these results suggest that the period of 30-36 months of age might see a transition in which children became more faithful imitators, and faithful imitation also became more important in understanding their development. In particular, normative reasoning of labels and artifact functions also jumped between 30-36 months of age (and not between 24-30 mo or 36-42 mo), and normative reasoning of artifact functions was specifically correlated with means-directed imitation (and not goal-directed or total imitation) at 36 months of age. Therefore the increasing understanding about norms and conventions when children turn three may be a good candidate to explain a specific increase in means-directed imitation at that time.

CHAPTER 4

DISCUSSION

This project started with three aims: to explore individual differences in children's imitative behavior; to connect imitation with other aspects of development; and to track developmental changes in imitation. Results from children's three visits have provided insights to all these three aims.

Consistent with my hypothesis, I found stable individual differences both within and between imitation tasks. Results showed that during children's imitative behavior correlated between different trials in the puzzle box task, and between different conditions in the puppet show task. Furthermore, the individual differences in imitative behavior was stable across tasks—children who focused on copying the goal in the puppet show task also copied more necessary actions in the puzzle box task, and children who focused on coping the means in the puppet show task copied more unnecessary actions in the puzzle box task. Given that the goals in the two tasks are set up very differently—the puzzle box task featured instrumental goals, and the puppet show tasks featured social goals—these correlations show that the observed individual differences transcend immediate contextual influences such as the type of goals of a particular task. I further employed canonical correlation analysis to confirm and clarify these intercorrelations. Below I explain the implications of these two factors in understanding children's imitative behavior.

The factor of means-directed imitation shows high loadings on children's copying the model's manner in the puppet show task, and copying unnecessary actions in the puzzle box task. This factor can be explained in several ways. For example, it is possible that it represents children's working memory—those high on working memory may have remembered the details of the model's actions more clearly and therefore are able to reproduce them more exactly. However, given that 18-months-old infants are able to complete both the puppet show task and puzzle box task, and at least sometimes reproduce the unnecessary aspects of these tasks (Bekkering, et al., 2000; Carpenter, et al., 2005; Nielsen, 2006), it is unlikely that the memory load for these tasks posts heavy restraints on the 2-year-old children's' performance. It is equally unlikely that this factor represents children's fine motor skill, given that all of these actions are easy to perform, and that the unnecessary actions did not require any more fine motor skills than the necessary actions. Similarly, being detail-oriented also cannot explain why this factor has high loadings on imitating unnecessary actions rather than necessary actions, given that the unnecessary actions and necessary actions are similar in saliency.

In my view this factor represents variability in children's *choice* to reproduce the goal-irrelevant aspects of the model's actions. By choice I do not mean children consciously manage their behavior, but rather they have the flexibility to focus on copying the goal, the means, both, or neither. The particular way children imitate in a particular task reflects their understanding of the task, which is affected by children's personal traits, expectations formed from previous experiences, and contextual effects. My view contrasts with views which suggest copying irrelevant actions to be inevitable because of children's cognitive constraints (e.g., Lyons, et al., 2007). One reason why children imitate irrelevant actions, suggested by current data, is their normative reasoning. In my study, an increase in imitating unnecessary actions between 30 and 36 months of age correspond to an increase in children's understanding that labels are shared between different people, and that artifacts are designed for particular functions. Among individual 36-months-old children, their normative understanding of artifact functions also specifically predicts means-directed imitation. Therefore normative reasoning may explain the jump of means-directed imitation between 30 and 36 months of age, although this effect might be specific to that particular age. It is possible that other factors, such as social affiliation (Over & Carpenter, 2012), dominates whether children copy irrelevant actions for a different age range or context.

The factor of goal-directed imitation takes two forms: when an external goal of the demonstrated action is salient (such as the house in the House condition of the puppet show task, or the reward in the puzzle box task), children high on goal-directed imitation are more likely to match the goal (put the puppet in the same house, or retrieve the reward), as well as to copy the actions that leads to the goal (necessary actions in the puzzle box task). On the other hand, when an external goal is absent (such as No house condition in the puppet show task), these children are more likely to imitate all aspects of the action, including both its manner and its end state. As in the case of method-directed imitation, there are multiple possible explanations for the goal-directed imitation. First, goal-directed imitation may reflect children's own strong motivation to achieve the goal, such as to retrieve the reward. However, this doesn't explain why when there is no clear instrumental goal (such as in the No House condition of the puppet show task), children high on goal-directed imitation care to imitate the manner of the action. Second, goal-directed imitation may reflect children's sensitivity to contextual cues and their flexibility in modifying behavior given changes in context. This account can explain why children high on goal-directedness flexibly switch focus of imitation between the two conditions in the puppet show task, and may relate children's imitative behavior to their executive function (especially mental flexibility). However, this account alone does not explain the specific direction of children's switch—it does not address why children are more likely to match final location in the House condition and to match manner in the No House condition, but not the reverse.

I argue that, again, variability in goal-directedness in imitation reflects a *choice* children make. This time the choice is to match the model's intentions in performing these actions, which can be either instrumental (to retrieve a reward, or to put a puppet into a house), or social (to move a puppet in a particular manner). One support for this hypothesis is that after controlling for age, developmental level, and language, goal-directed imitation correlates with children's Theory-of-Mind score at 24 months. It suggests that goal-directed imitation may either *reflect* children's understanding of others' mental states, or *help* in understanding others' mental states. This is consistent with previous work showing that infant's attention towards intentional action predicts Theory-of-Mind in preschool years (Wellman, et al., 2008). Besides Theory-of-Mind, goal-directed imitation score also correlates with children's sharing behavior at 24 months. Note that the sharing scenario used in this project involved some mental state inference about the doggie (e.g., "receiving stickers will make doggie happy"), it is likely that this correlation also reflects mental states understanding. Goal-directed imitation also correlates with children's developmental level at 30 and 36 months and language at 36 months, which suggests that imitating the goals is also broadly associated with the overall level of development.

Critically, the correlates between the two imitation factors and other aspects of development, and even the two factors themselves, may very well change with age. Actually, results from children's later visits revealed several changes: First, on a group level, there is a significant increase in imitation fidelity between 30 and 36 months of age. Second, by 36 months of age other measurements were better predicted by the composite score of means-directed imitation, but not the composite score of goal-directed imitation. These changes points to a general trend that means-directed imitation may become more prominent and also more important (in terms of predicting other aspects of development) when children turn from age 2 to 3. Further analysis is needed to confirm this trend and to investigate its causes, but it is important to note that not only the extent, but also the structure of imitative behavior changes along with age.

Another important observation is that the goal-directed and means-directed imitation are not two ends of a dichotomy—in fact, children's goal-directed and means-directed imitation scores are positively correlated. This is easy to understand—children can vary from not imitating at all (thus low on both factors) to imitating all components of the model (thus high on both factors). These two factors may together represent a broader construct which captures how likely individual children are to imitate in any given social interaction.

That being said, a unique contribution of this dissertation is to prove that goal-directed and means-directed imitation are correlated but distinctive. They are distinctive in terms of developmental trajectory (e.g., means-directed imitation has a sharper increase between 30 and 36 months), they are each embodied in a separate set of imitation measurements (e.g., imitation of unnecessary versus necessary actions), and most importantly, they are associated with different aspects of development. For example, many of the correlations between imitation and other measurements would not be observed if I only used a total imitation score. By distinguishing and measuring these two dimensions in imitation, it is possible to discover new aspects of stable individual difference, and to deepen our understanding about how and why children imitate.

These correlations have implications on the broader question about continuity in individual differences between infancy and preschool years. It has long been known that individual differences captured by traditional infant tests (such as the Bayley Scales of Infant Development, Bayley, 2005) do not tap the same dimensions as captured by traditional preschooler tests (such as WPPSI, Wechsler, 1967). However, preschool IQ can be predicted on individual differences in infant's general information processing capacities, such as their attention towards familiar and novel objects (Bornstein, 1985). Recent studies suggested that besides this general factor, there are also domain-specific continuities, and one of the most researched domains is social cognition. Studies have shown that preschool Theory-of-Mind score is predicted by habituation rate towards intentional actions at 6, 11, and 14 months (Aschersleben, Hofer, & Jovanovic, 2008; Wellman, et al., 2008; Wellman, Phillips, Dunphy-Lelii, & LaLonde, 2004), attention towards helpers over hinders at 12 months (Yamaguchi, Kuhlmeier, Wynn, & VanMarle, 2009), and anticipatory looking in the false-belief task at 18 months (Thoermer, Sodian, Vuori, Perst, & Kristen, 2012). Moreover, comprehension of referential pointing at 9 months of age can predict 15-months-old infants' performance in an intention-based imitation task (reenacting the intention of failed actions, Meltzoff, 1995), as well as production of internal state lexicon at 24 and 36 months of age (Kristen, Sodian, Thoermer, & Perst, 2011). Putting my dissertation in this context of research, it seems reasonable to assume that goal-direct imitation in 2-year-olds also falls on this continuum of social cognition. In fact, goal-directed imitation in toddlerhood may bridge looking-time based infantile social-cognitive measurements and interview-based preschool measurements.

This project also has a methodological contribution for developmental research. Despite the studies described in the last paragraph, research on individual differences is largely underrepresented in the literature of children's learning and cognition. A majority of research explores what infants and children are *capable* to do or to learn, but I argue that understanding what intrinsic and extrinsic factors leads children to *choose* to do or to learn in a particular scenario is also important. Understanding these intrinsic and extrinsic factors not only provides insights on the mechanisms of children's learning and cognition, but may also help building an environment that facilitates individual children's learning and development.

One interesting future question is to study individual differences in social learning mechanisms other than imitation. As mentioned in the introduction, children do not always imitate either the goal or the means after watching a demonstration, they frequently engage in exploration or innovation. For example, in my experiments they explore the causal mechanisms of an apparatus without trying to match what the model did (e.g., trying to activate every movable parts of a puzzle box); they also invent new ways to retrieve the goal, or even create a new goal for the task (e.g., tilting the puzzle box and dumping the reward, or making up a story about a puppet and a house).

Importantly, these behavior do not occur because children merely ignored the demonstration and applied individual learning strategies instead; these behavior can actually be socially motivated (such as in the case of story-telling), and can represent a *choice* to do something else other than just copying.

Related to this, another interesting area for future exploration is the learning outcome resulting from individual differences in social learning. For example, for children who always imitate faithfully, will they be more efficient in gaining new skills, but lose a chance to think about the model's goal or to understand the casual mechanism? Will they prefer social learning or help seeking over individual learning when meeting obstacles? Will there be implications for the development of a particular mindset, or the development of critical thinking skills in the future? Also, what types of environment and social facilitations are suitable for a faithful imitator, a goal-directed imitator, or an inventor?

In conclusion, this dissertation provides a first demonstration of how analyzing individual differences can contribute to our understanding of children's imitative behavior. Specifically, I showed a goal-directed factor and a means-directed factor underlying the variance observed in 2-year-old toddlers' imitation. These two factors have different developmental trajectories, and correlate with different aspects of children's development. The discovery of these two factors sheds light on the mechanisms of children’s social learning, and has potential implications on facilitating children’s learning based on individual children’s learning style.

REFERENCES

Aschersleben, G., Hofer, T., & Jovanovic, B. (2008). The link between infant attention to goal-directed action and later theory of mind abilities. *Developmental Science, 11*(6), 862-868. doi: 10.1111/j.1467-7687.2008.00736.x

Asendorpf, J. B., Warkentin, V., & Baudonnière, P. M. (1996). Self-awareness and other-awareness. II: Mirror self-recognition, social contingency awareness, and synchronic imitation. *Developmental Psychology*, *32*(2), 313. doi: 10.1037/0012-1649.32.2.313

Bayley, N. (2005). *Bayley scales of infant and toddler development* (3rd ed.). San Antonio, TX: Harcourt Assessment.

Bekkering, H., Wohlschlager, A., & Gattis, M. (2000). Imitation of gestures in children is goal-directed. *The Quarterly Journal of Experimental Psychology: Section A, 53*(1), 153-164. doi: 10.1080/713755872

Bellagamba, F., Camaioni, L., & Colonnesi, C. (2006). Change in children's understanding of others' intentional actions. *Developmental Science, 9*(2), 182-188. doi: 10.1111/j.1467-7687.2006.00478.x

Beller, S. (2010). Deontic reasoning reviewed: Psychological questions, empirical findings, and current theories. *Cognitive Processing, 11*(2), 123-132. doi: 10.1007/s10339-009-0265-z

Bonawitz, E., Shafto, P., Gweon, H., Goodman, N. D., Spelke, E., & Schulz, L. (2011). The double-edged sword of pedagogy: Instruction limits spontaneous exploration and discovery. *Cognition, 120*(3), 322-330. doi: 10.1016/j.cognition.2010.10.001

Bornstein, M. H. (1985). Habituation of attention as a measure of visual information processing in human infants: Summary, systematization, and synthesis. In G. Gottleib & N. A. Krasnegor (Eds.), *Measurement of audition and vision in the first year of postnatal life: A methodological overview* (pp. 253-300). Norwood, NJ: Ablex.

Brugger, A., Lariviere, L. A., Mumme, D. L., & Bushnell, E. W. (2007). Doing the right thing: Infants' selection of actions to imitate from observed event sequences. *Child Development, 78*(3), 806-824. doi: 10.1111/j.1467-8624.2007.01034.x

Buchsbaum, D., Gopnik, A., Griffiths, T. L., & Shafto, P. (2011). Children's imitation of causal action sequences is influenced by statistical and pedagogical evidence. *Cognition, 120*(3), 331-340. doi: 10.1016/j.cognition.2010.12.001

Byrnl, R. W., & Tomasello, M. (1995). Do rats ape? *Animal behaviour, 50*(5), 1417-1420.

Call, J., Carpenter, M., & Tomasello, M. (2005). Copying results and copying actions in the process of social learning: chimpanzees (*Pan troglodytes*) and human children (*Homo sapiens*). *Animal Cognition, 8*(3), 151-163. doi: 10.1007/s10071-004-0237-8

Carlson, S. M., Mandell, D. J., & Williams, L. (2004). Executive function and theory of mind: Stability and prediction from ages 2 to 3. *Developmental Psychology, 40*(6), 1105. doi: 10.1037/0012-1649.40.6.1105

Carlson, S. M., & Moses, L. J. (2001). Individual differences in inhibitory control and children's theory of mind. *Child Development, 72*(4), 1032-1053.

Carpenter, M., Akhtar, N., & Tomasello, M. (1998). Fourteen- through 18-month-old infants differentially imitate intentional and accidental actions. *Infant Behavior and Development, 21*(2), 315-330. doi: 10.1016/s0163-6383(98)90009-1

Carpenter, M., Call, J., & Tomasello, M. (2002). Understanding “prior intentions” enables two-year-olds to imitatively learn a complex task. *Child Development, 73*(5), 1431-1441. doi: 10.1111/1467-8624.00481

Carpenter, M., Call, J., & Tomasello, M. (2005). Twelve- and 18-month-olds copy actions in terms of goals. *Developmental Science, 8*(1), F13-F20. doi: 10.1111/j.1467-7687.2004.00385.x

Casler, K., & Kelemen, D. (2005). Young children's rapid learning about artifacts. *Developmental Science, 8*(6), 472-480.

Casler, K., & Kelemen, D. (2007). Reasoning about artifacts at 24 months: The developing teleo-functional stance. *Cognition, 103*(1), 120-130. doi: 10.1016/j.cognition.2006.02.006

Casler, K., Terziyan, T., & Greene, K. (2009). Toddlers view artifact function normatively. *Cognitive Development, 24*(3), 240-247. doi: 10.1016/j.cogdev.2009.03.005

Chartrand, T. L., & Bargh, J. A. (1999). The chameleon effect: The perception–behavior link and social interaction. *Journal of personality and social psychology, 76*(6), 893-910. doi: 10.1037/0022-3514.76.6.893

Chartrand, T. L., & van Baaren, R. (2009). Human mimicry. *Advances in experimental social psychology*, *41*, 219-274.

Chernyak, N., & Kushnir, T. (2013). Giving preschoolers choice increases sharing behavior. *Psychological Science*, 0956797613482335.

Clegg, J. M. (2013). *The art of convention: cognitive foundations of cultural learning.*

Csibra, G., & Gergely, G. (2006). Social learning and social cognition: The case for pedagogy. In Y. Munakata & M. H. Johnson (Eds.), *Processes of change in brain and cognitive development: Attention and performance* (Vol. XXI, pp. 249-274). New York, NY: Oxford University Press.

Csibra, G., & Gergely, G. (2009). Natural pedagogy. *Trends in Cognitive Sciences, 13*(4), 148-153. doi: 10.1016/j.tics.2009.01.005

Cummins, D. D. (1996). Evidence of deontic reasoning in 3-and 4-year-old children. *Memory & Cognition*, *24*(6), 823-829. doi: 10.3758/BF03201105

DiYanni, C., & Kelemen, D. (2008). Using a bad tool with good intention: Young children's imitation of adults' questionable choices. *Journal of Experimental Child Psychology, 101*(4), 241-261. doi: 10.1016/j.jecp.2008.05.002

Fenson, L., Pethick, S., Renda, C., Cox, J. L., Dale, P. S., & Reznick, J. S. (2000). Short-form versions of the MacArthur communicative development inventories. *Applied Psycholinguistics, 21*(1), 95-116.

Flynn, E., & Whiten, A. (2010). Studying children's social learning experimentally "in the wild". *Learning & behavior, 38*(3), 284-296.

Flynn, E., & Whiten, A. (2012). Experimental "Microcultures" in young children: Identifying biographic, cognitive, and social predictors of information transmission. *Child Development, 83*(3), 911-925. doi: 10.1111/j.1467-8624.2012.01747.x

Galef Jr, B. G. (1988). Imitation in animals: History, definition, and interpretation of data from the psychological laboratory. In T. R. Zentall & B. G. Galef Jr (Eds.), *Social learning: Psychological and biological perspectives* (pp. 3-28). Hillsdale, NJ: Erlbaum.

Gergely, G., Bekkering, H., & Király, I. (2002). Rational imitation in preverbal infants. *Nature, 415*(6873), 755. doi: 10.1038/415755a

Hamlin, J. K., Hallinan, E. V., & Woodward, A. L. (2008). Do as I do: 7-month-old infants selectively reproduce others' goals. *Developmental Science, 11*(4), 487-494. doi: 10.1111/j.1467-7687.2008.00694.x

Harnick, F. S. (1978). The relationship between ability level and task difficulty in producing imitation in infants. *Child Development*, 209-212.

Harris, P. L., & Núntez, M. (1996). Understanding of permission rules by preschool children. *Child Development, 67*(4), 1572-1591. doi: 10.1111/j.1467-8624.1996.tb01815.x

Haun, D. B., Rekers, Y., & Tomasello, M. (2012). Majority-biased transmission in chimpanzees and human children, but not orangutans. *Current Biology, 22*(8), 727-731.

Haun, D. B., Van Leeuwen, E. J., & Edelson, M. G. (2013). Majority influence in children and other animals. *Developmental cognitive neuroscience, 3*, 61-71.

Henderson, A. M. E., & Graham, S. A. (2005). Two-year-olds' appreciation of the shared nature of novel object labels. *Journal of Cognition and Development, 6*(3), 381-402. doi: 10.1207/s15327647jcd0603_4

Herrmann, P. A., Legare, C. H., Harris, P. L., & Whitehouse, H. (2013). Stick to the script: The effect of witnessing multiple actors on children's imitation. *Cognition, 129*(3), 536-543.

Heyes, C. M. (1995). Imitation and flattery: a reply to Byrne & Tomasello. *Animal behaviour, 50*(5), 1421-1424.

Heyes, C. M. (2011). Automatic imitation. *Psychological Bulletin, 137*(3), 463.

Hilbrink, E. E., Sakkalou, E., Ellis-Davies, K., Fowler, N. C., & Gattis, M. (2013). Selective and faithful imitation at 12 and 15 months. *Developmental Science, 16*(6), 828-840. doi: 10.1111/desc.12070

Horner, V., & Whiten, A. (2005). Causal knowledge and imitation/emulation switching in chimpanzees (*Pan troglodytes*) and children (*Homo sapiens*). *Animal Cognition, 8*(3), 164-181. doi: 10.1007/s10071-004-0239-6

Horowitz, A. C. (2003). Do humans ape? Or do apes human? Imitation and intention in humans (Homo sapiens) and other animals. *Journal of Comparative Psychology, 117*(3), 325.

Hurley, S., & Chater, N. (2005). *Perspectives on Imitation: From Neuroscience to Social Science* (Vol. 1): MIT Press.

Ireton, H. (1992). *Child development inventory manual*: Behavior Science Systems.

Janik, V. M., & Slater, P. J. B. (2000). The different roles of social learning in vocal communication. *Animal behaviour, 60*(1), 1-11.

Kenward, B. (2012). Over-imitating preschoolers believe unnecessary actions are normative and enforce their performance by a third party. *Journal of Experimental Child Psychology, 112*(2), 195-207. doi: 10.1016/j.jecp.2012.02.006

Kenward, B., Karlsson, M., & Persson, J. (2011). Over-imitation is better explained by norm learning than by distorted causal learning. *Proceedings of the Royal Society B: Biological Sciences, 278*(1709), 1239-1246. doi: 10.1098/rspb.2010.1399

Kessels, R. P. C., van Zandvoort, M. J. E., Postma, A., Kappelle, L. J., & de Haan, E. H. F. (2000). The Corsi block-tapping task: standardization and normative data. *Applied neuropsychology, 7*(4), 252-258.

Keupp, S., Behne, T., & Rakoczy, H. (2013). Why do children overimitate? Normativity is crucial. *Journal of Experimental Child Psychology, 116*(2), 392-406.

Keupp, S., Behne, T., Zachow, J., Kasbohm, A., & Rakoczy, H. (2015). Over-imitation is not automatic: Context sensitivity in children's overimitation and action interpretation of causally irrelevant actions. *Journal of Experimental Child Psychology, 130*, 163-175.

Kinzler, K. D., Corriveau, K. H., & Harris, P. L. (2011). Children's selective trust in native‐accented speakers. *Developmental Science, 14*(1), 106-111.

Király, I. (2009). The effect of the model's presence and of negative evidence on infants' selective imitation. *Journal of Experimental Child Psychology, 102*(1), 14-25. doi: 10.1016/j.jecp.2008.06.003

Király, I., Csibra, G., & Gergely, G. (2004). *The role of communicative-referential cues in observational learning during the second year*. Paper presented at the the 14th Biennial International Conference on Infant Studies.

Koenig, M. A., Clément, F., & Harris, P. L. (2004). Trust in testimony: Children's use of true and false statements. *Psychological Science, 15*(10), 694-698.

Kristen, S., Sodian, B., Thoermer, C., & Perst, H. (2011). Infants' joint attention skills predict toddlers' emerging mental state language. *Developmental Psychology, 47*(5), 1207.

Kuhl, P. K., & Meltzoff, A. N. (1996). Infant vocalizations in response to speech: Vocal imitation and developmental change. *The journal of the Acoustical Society of America, 100*(4), 2425-2438.

Lyons, D., Damrosch, D., Lin, J., Macris, D., & Keil, F. (2011). The scope and limits of overimitation in the transmission of artefact culture. *Philosophical Transactions of the Royal Society B: Biological Sciences, 366*(1567), 1158-1167. doi: 10.1098/rstb.2010.0335

Lyons, D., Young, A., & Keil, F. (2007). The hidden structure of overimitation. *Proceedings of the National Academy of Sciences, 104*(50), 19751-19756. doi: 10.1073/pnas.0704452104

McGuigan, N., Makinson, J., & Whiten, A. (2011). From over-imitation to super-copying: Adults imitate causally irrelevant aspects of tool use with higher fidelity than young children. *British Journal of Psychology, 102*(1), 1-18. doi: 10.1348/000712610x493115

McGuigan, N., & Whiten, A. (2009). Emulation and "overemulation" in the social learning of causally opaque versus causally transparent tool use by 23- and 30-month-olds. *Journal of Experimental Child Psychology, 104*(4), 367-381. doi: 10.1016/j.jecp.2009.07.001

McGuigan, N., Whiten, A., Flynn, E., & Horner, V. (2007). Imitation of causally opaque versus causally transparent tool use by 3- and 5-year-old children. *Cognitive Development*, *22*(3), 353-364. doi: 10.1016/j.cogdev.2007.01.001

Meltzoff, A. N. (1988). The human infant as Homo imitans. *Social learning: Psychological and biological perspectives*, 319-341.

Meltzoff, A. N. (1995). Understanding the intentions of others: Re-enactment of intended acts by 18-month-old children. *Developmental Psychology, 31*(5), 838-850. doi: 10.1037/0012-1649.31.5.838

Nagell, K., Olguin, R. S., & Tomasello, M. (1993). Processes of social learning in the tool use of chimpanzees (*Pan troglodytes*) and human children (*Homo sapiens*). *Journal of Comparative Psychology, 107*(2), 174-186. doi: 10.1037/0735-7036.107.2.174

Nielsen, M. (2006). Copying actions and copying outcomes: Social learning through the second year. *Developmental Psychology, 42*(3), 555-565. doi: 10.1037/0012-1649.42.3.555

Nielsen, M. (2009). 12-month-olds produce others' intended but unfulfilled acts. *Infancy, 14*(3), 377-389. doi: 10.1080/15250000902840003

Nielsen, M., & Blank, C. (2011). Imitation in young children: When who gets copied is more important than what gets copied. *Developmental Psychology, 47*(4), 1050-1053. doi: 10.1037/a0023866

Nielsen, M., Moore, C., & Mohamedally, J. (2012). Young children overimitate in third-party contexts. *Journal of Experimental Child Psychology, 112*(1), 73-83. doi: 10.1016/j.jecp.2012.01.001

Nielsen, M., Mushin, I., Tomaselli, K., & Whiten, A. (2014). Where Culture Takes Hold: “Overimitation” and Its Flexible Deployment in Western, Aboriginal, and Bushmen Children. *Child Development, 85*(6), 2169-2184. doi: 10.1111/cdev.12265

Nielsen, M., Simcock, G., & Jenkins, L. (2008). The effect of social engagement on 24-month-olds’ imitation from live and televised models. *Developmental Science, 11*(5), 722-731. doi: 10.1111/j.1467-7687.2008.00722.x

Nielsen, M., Slaughter, V., & Dissanayake, C. (2013). Object-Directed Imitation in Children With High-Functioning Autism: Testing the Social Motivation Hypothesis. *Autism Research, 6*(1), 23-32. doi: 10.1002/aur.1261

Nielsen, M., & Tomaselli, K. (2010). Overimitation in Kalahari Bushman children and the origins of human cultural cognition. *Psychological Science, 21*(5), 729-736. doi: 10.1177/0956797610368808

Over, H., & Carpenter, M. (2012). Putting the social into social learning: Explaining both selectivity and fidelity in children's copying behavior. *Journal of Comparative Psychology, 126*(2), 182-192. doi: 10.1037/a0024555

Over, H., & Carpenter, M. (2013). The social side of imitation. *Child Development Perspectives*, *7*(1), 6-11. doi: 10.1111/cdep.12006

Perra, O., & Gattis, M. (2008). Reducing the mapping between perception and action facilitates imitation. *British Journal of Developmental Psychology, 26*(1), 133-144.

Putnam, S. P., Gartstein, M. A., & Rothbart, M. K. (2006). Measurement of fine-grained aspects of toddler temperament: The Early Childhood Behavior Questionnaire. *Infant Behavior and Development, 29*(3), 386-401.

Rakoczy, H. (2008). Taking fiction seriously: Young children understand the normative structure of joint pretence games. *Developmental Psychology, 44*(4), 1195. doi: 10.1037/0012-1649.44.4.1195

Rakoczy, H., Warneken, F., & Tomasello, M. (2008). The sources of normativity: Young children's awareness of the normative structure of games. *Developmental Psychology, 44*(3), 875-881. doi: 10.1037/0012-1649.44.3.875

Rothbart, M. K., Ahadi, S. A., Hershey, K. L., & Fisher, P. (2001). Investigations of Temperament at Three to Seven Years: The Children's Behavior Questionnaire. *Child Development, 72*(5), 1394-1408. doi: 10.1111/1467-8624.00355

Schmidt, M. F. H., Rakoczy, H., & Tomasello, M. (2011). Young children attribute normativity to novel actions without pedagogy or normative language. *Developmental Science, 14*(3), 530-539. doi: 10.1111/j.1467-7687.2010.01000.x

Schulz, L. E., Hooppell, C., & Jenkins, A. C. (2008). Judicious imitation: Children differentially imitate deterministically and probabilistically effective actions. *Child Development, 79*(2), 395-410. doi: 10.1111/j.1467-8624.2007.01132.x

Simpson, A., & Riggs, K. J. (2011). Three- and 4-year-olds encode modeled actions in two ways leading to immediate imitation and delayed emulation. *Developmental Psychology, 47*(3), 834-840. doi: 10.1037/a0023270

Southgate, V., Chevallier, C., & Csibra, G. (2009). Sensitivity to communicative relevance tells young children what to imitate. *Developmental Science, 12*(6), 1013-1019. doi: 10.1111/j.1467-7687.2009.00861.x

Thoermer, C., Sodian, B., Vuori, M., Perst, H., & Kristen, S. (2012). Continuity from an implicit to an explicit understanding of false belief from infancy to preschool age. *British Journal of Developmental Psychology, 30*(1), 172-187. doi: 10.1111/j.2044-835X.2011.02067.x

Thorpe, W. H. (1963). *Learning and instinct in animals* (2nd ed.). Cambridge, MA: Havard University Press.

Tomasello, M., Kruger, A. C., & Ratner, H. H. (1993). Cultural learning. *Behavioral and Brain Sciences, 16*(03), 495-511.

Užgiris, I. C. (1981). Two functions of imitation during infancy. *International Journal of Behavioral Development, 4*(1), 1-12. doi: 10.1177/016502548100400101

Wang, Y., Newport, R., & Hamilton, A. F. d. C. (2011). Eye contact enhances mimicry of intransitive hand movements. *Biology Letters, 7*(1), 7-10. doi: 10.1098/rsbl.2010.0279

Want, S. C., & Harris, P. L. (2001). Learning from other people's mistakes: Causal understanding in learning to use a tool. *Child Development, 72*(2), 431-443. doi: 10.1111/1467-8624.00288

Want, S. C., & Harris, P. L. (2002). How do children ape? Applying concepts from the study of non-human primates to the developmental study of 'imitation' in children. *Developmental Science, 5*(1), 1-14. doi: 10.1111/1467-7687.00194

Watson-Jones, R. E., Legare, C. H., Whitehouse, H., & Clegg, J. M. (2014). Task-specific effects of ostracism on imitative fidelity in early childhood. *Evolution and Human Behavior, 35*(3), 204-210. doi: 10.1016/j.evolhumbehav.2014.01.004

Wechsler, D. (1967). *Wechsler preschool and primary scale of intelligence*. New York: Psychological Corporation.

Wellman, H. M., Cross, D., & Watson, J. (2001). Meta-Analysis of Theory-of-Mind Development: The Truth about False Belief. *Child Development, 72*(3), 655-684. doi: 10.1111/1467-8624.00304

Wellman, H. M., & Liu, D. (2004). Scaling of Theory-of-Mind Tasks. *Child Development, 75*(2), 523-541. doi: 10.1111/j.1467-8624.2004.00691.x

Wellman, H. M., Lopez-Duran, S., LaBounty, J., & Hamilton, B. (2008). Infant attention to intentional action predicts preschool theory of mind. *Developmental Psychology, 44*(2), 618-623. doi: 10.1037/0012-1649.44.2.618

Wellman, H. M., Phillips, A. T., Dunphy-Lelii, S., & LaLonde, N. (2004). Infant social attention predicts preschool social cognition. *Developmental Science, 7*(3), 283-288.

Whiten, A. (2002). *Imitation of sequential and hierarchical structure in action: experimental studies with children and chimpanzees.* Paper presented at the Imitation in animals and artifacts.

Whiten, A., Custance, D. M., Gomez, J.-C., Teixidor, P., & Bard, K. A. (1996). Imitative learning of artificial fruit processing in children (*Homo sapiens*) and chimpanzees (*Pan troglodytes*). *Journal of Comparative Psychology, 110*(1), 3-14. doi: 10.1037/0735-7036.110.1.3

Whiten, A., & Flynn, E. (2010). The transmission and evolution of experimental microcultures in groups of young children. *Developmental Psychology, 46*(6), 1694.

Whiten, A., Horner, V., & Marshall-Pescini, S. (2005). Selective imitation in child and chimpanzee: A window on the construal of others' actions. In S. Hurley & N. Chater (Eds.), *Perspectives on imitation: Mechanisms of imitation and imitation in animals* (Vol. 1, pp. 263-283). Cambridge, MA: MIT Press.

Whiten, A., McGuigan, N., Marshall-Pescini, S., & Hopper, L. M. (2009). Emulation, imitation, over-imitation and the scope of culture for child and chimpanzee. *Philosophical Transactions of the Royal Society B: Biological Sciences, 364*(1528), 2417-2428. doi: 10.1098/rstb.2009.0069

Wilks, M., Collier-Baker, E., & Nielsen, M. (2014). Preschool children favor copying a successful individual over an unsuccessful group. *Developmental Science*.

Williamson, R. A., Jaswal, V. K., & Meltzoff, A. N. (2010). Learning the rules: Observation and imitation of a sorting strategy by 36-month-old children. *Developmental Psychology, 46*(1), 57-65. doi: 10.1037/a0017473

Williamson, R. A., & Markman, E. M. (2006). Precision of imitation as a function of preschoolers' understanding of the goal of the demonstration. *Developmental Psychology, 42*(4), 723-731. doi: 10.1037/0012-1649.42.4.723

Williamson, R. A., Meltzoff, A. N., & Markman, E. M. (2008). Prior experiences and perceived efficacy influence 3-year-olds' imitation. *Developmental Psychology, 44*(1), 275-285. doi: 10.1037/0012-1649.44.1.275

Wohlgelernter, S., Diesendruck, G., & Markson, L. (2010). What is a conventional object function? The effects of intentionality and consistency of use. *Journal of Cognition and Development, 11*(3), 269-292. doi: 10.1080/15248371003699985

Wood, L. A., Kendal, R. L., & Flynn, E. G. (2012). Context-dependent model-based biases in cultural transmission: children's imitation is affected by model age over model knowledge state. *Evolution and Human Behavior, 33*(4), 387-394. doi: 10.1016/j.evolhumbehav.2011.11.010

Woodward, A. L. (1998). Infants selectively encode the goal object of an actor's reach. *Cognition, 69*(1), 1-34. doi: 10.1016/S0010-0277(98)00058-4

Yamaguchi, M., Kuhlmeier, V. A., Wynn, K., & VanMarle, K. (2009). Continuity in social cognition from infancy to childhood. *Developmental Science, 12*(5), 746-752. doi: 10.1111/j.1467-7687.2008.00813.x

Yu, Y., & Kushnir, T. (2011). It’s all about the game: Infants’ action strategies during imitation are influenced by their prior expectations. *Proceedings of the 33rd Annual Conference of the Cognitive Science Society*, 3570-3574.

Yu, Y., & Kushnir, T. (2014). Social context effects in 2- and 4-year-olds' selective versus faithful imitation. *Developmental Psychology, 50*(3), 922-933. doi: 10.1037/a0034242

Zmyj, N., Buttelmann, D., Carpenter, M., & Daum, M. M. (2010). The reliability of a model influences 14-month-olds' imitation. *Journal of Experimental Child Psychology, 106*(4), 208-220. doi: DOI: 10.1016/j.jecp.2010.03.002

APPENDICE

Appendix 1. List of all measurements and coding schemes

IMTramp, IMTrake, IMTflowerbox: Imitation, Set 1, Brugger's toys

IMT_complete $\in \{1,2,3,4\}$	#If the child completed the task (1: experimenter did not administrate, 2: child did not participate, 3: child did participate but did not finish, 4: child completed the task)
IMT_distract $\in \mathbb{N}_0$	#Number of time children got distracted during this task (looked away for more than 5 sec when they are supposed to be watching/reacting)
IMT_time $\in \mathbb{N}_0$	#Amount of time (in second) that children engaged in this task (exclude distracted time)
IMT_respondtime $\in \mathbb{N}_0$	#Amount of time (in second) starting from baby first touched the toy and ended when they first touched the piece or the toy is taken away (exclude distracted time)
IMT_act, string	#A sequence of letters (ABCDE) corresponding to child's action sequence, end either when they touched the piece (C) or the toy is taken away
IMT_retrieval $\in \{1,2\}$	#1 if they got the piece (C), 2 if not
IMT_unnecessary $\in \{1,2\}$	#1 if they did the unnecessary action (A), 2 if not
IMT_strategy $\in \{1,2,3,4\}$	#See below

		ramp (purple)	rake (green)	flowerbox (orange)
A	first target action	remove barrier	cover hole	remove Velcro latch
B	second target action	push the piece with the pusher	pull out a T-shaped paddle	pull open the lid

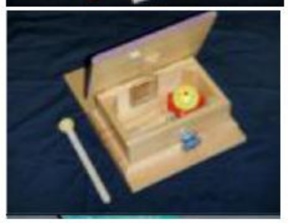
Item	Code	Description
Individual actions	A	Demonstrator’s first action (see Figure 1)
	B	Demonstrator’s second action (see Figure 1)
	C	Demonstrator’s final action—pick up the piece
	D	Actions with the toy box that had not been demonstrated, aiming at retrieving the piece (e.g., for the “Rake”, leaning and shaking the toy box to get the piece slide out)
	E	Actions with the toy box that had not been demonstrated, not aiming at retrieving the piece (e.g., for the “Ramp”, putting back the barrier after pulling it out)
Imitative behavior	1“A+B”	Performing actions A, B, C in the exact order, no additional actions
	2“B only”[a]	Performing actions B, C in the exact order, no additional actions
	3“Other”	Any other way of retrieval, include 3 subcategories as listed below:
	-31reversal[a]	Reversing the order of actions A and B (e.g., performing “B, A, C”)
	-32additional actions	Adding additional actions which were not demonstrated (e.g., performing “A, E, B, E, C”). The additional action need to be distinctive; pausing during performing an action or accidentally touching other parts of the toy box doesn’t qualify additional action
	-33own way	Using a different way to retrieve the piece (e.g., performing “D, C”)
	-5 didn’t do	No action

Priority for “Other”: 33, 32, 31 – i.e., when children performed both D and E, code as 33; when they performed something like “B, A, E, C”, code as 32

IMTblue, IMTswitch, IMTartificial: Imitation, Set 2, Nielson's toys

IMT_complete $\in \{1,2,3,4\}$	#If the child completed the task (1: experimenter did not administrate, 2: child did not participate, 3: child did participate but did not finish, 4: child completed the task)
IMT_distract $\in \mathbb{N}_0$	#Number of time children got distracted during this task (looked away for more than 5 sec when they are supposed to be watching/reacting)
IMT_time $\in \mathbb{N}_0$	#Amount of time (in second) that children engaged in this task (exclude distracted time)
IMT_respondtime $\in \mathbb{N}_0$	#Amount of time (in second) starting from child first touched the toy and ended when they first touched the piece or the toy is taken away (exclude distracted time)
IMT_retrieval $\in \{1,2\}$	#1 if they got the object, 2 if not
IMT_unnecessary $\in \{1,2,3\}$	#1 if children imitated the unnecessary action (Action 1 in the table above) accurately (i.e. did the same motion as the experimenter, and on the same surface of the toy), 2 if children did the unnecessary action inaccurately (i.e., the motion is different), but the child is attempting to reproduce an unnecessary action (e.g., doing a similar action on the box with the stick), 3 if children did not do the action
IMT_necessary $\{1,2,3,4\}$	#1 if children used the tool to solve the mechanism (Action 2 in the table above), 2 if children used hand to solve the mechanism (but not 4), 3 if children did not solve the mechanism, 4 if the experimenter used hand to solve the mechanism and child also used hand to solve the mechanism
IMT_strategy $\in \{1,2,3,4\}$	#See below

Table 1
Apparatuses and associated actions.

Box label	Box closed	Box open	Action 1	Action 2	End result
Blue Box			Place red stick on top of box and wipe around in a circular motion three times	Hold stick on top of knob, push down, and in so doing open front of box	Remove bell toy and shake several times
Switch Box			Tap mallet on top of box three times	Using mallet, push switch from left to right to open box	Remove castanet and "click" several times
Artificial Fruit			Wipe blue stick along box from back to front three times	Using blue stick, push out dowels toward front until they fall onto top of table	Pull lid open and remove monkey

Item	Code	Description
Individual actions	A	Demonstrator's first action (unnecessary), A1 accurate, A2 inaccurate
	B	Demonstrator's second action (necessary), B1 with tool, B2 with hand
	C	Pick up the toy
	D	Actions with the toy box other than A and B, aiming at retrieving the piece
	E	Actions with the toy box that had not been demonstrated, not aiming at retrieving the piece (e.g., for the "Ramp", putting back the barrier after pulling it out)
Imitative behavior	1 faithful imitation	Performing the demonstrated actions in the exact order, no additional actions (1 for IMT_unnecessary and IMT_necessary), or, in the case that the experimenter used hand to do the necessary action, child performing unnecessary action + hand should be considered faithful imitation (A1B1C, or A1B2C when IMT_necessary code is 4)
	2 selective imitation	Performing only the necessary actions, no additional actions (3 for IMT_unnecessary and 2 or 4 for IMT_necessary). No matter how the

	experimenter demonstrated the necessary action. (B2C)
4 faithful + selective	Combination of faithful and selective imitation, same order, no additional actions (only when the demonstrator used tool for the necessary action)
- 41	1 for IMT_unnecessary (did the unnecessary action) and 2 for IMT_necessary (use hand) (A1B2C)
- 42	2 or 3 for IMT_unncessary (did not do the unnecessary action) and 1 for IMT_necessary (use tool) (B1C)
- 43	2 for unnecessary action and 2 for necessary action (A2B2C)
- 44	2 for unnecessary action and 1 for necessary action (A2B1C)
3“Other”	Any other way of retrieval, include 3 subcategories as listed below:
- 31Reversal	Reversing the order of necessary and unnecessary actions
- 32additional actions	Adding additional actions which were not demonstrated (exploring and experimenting with the toy).
- 33own way	Using a different way to retrieve the piece (action sequence include D).
- 5 didn’t do	No action

Priority for “Other”: 33, 32, 31

IMTclear, IMTmonkey, IMTprize: Imitation, Set 3, Horner's and Lyon's toys

IMT_complete $\in \{1,2,3,4\}$	#If the child completed the task (1: experimenter did not administrate, 2: child did not participate, 3: child did participate but did not finish, 4: child completed the task)
IMT_distract $\in \mathbb{N}_0$	#Number of time children got distracted during this task (looked away for more than 5 sec when they are supposed to be watching/reacting)
IMT_time $\in \mathbb{N}_0$	#Amount of time (in second) that children engaged in this task (exclude distracted time)
IMT_respondtime $\in \mathbb{N}_0$	#Amount of time (in second) starting from baby first touched the toy and ended when they first touched the ball or the toy is taken away (exclude distracted time)
IMT_retrieval $\in \mathbb{N}_0$	#Number of times they retrieved the ball
IMT_U1_F $\in \{1,2,3\}$	#How children carry out U1 in their first attempt (1: Accurate, 2: Inaccurate, 3: Did not do)
IMT_U1_W $\in \{1,2,3\}$	#Children's best carry out of U1 in the whole period (1: Accurate, 2: Inaccurate, 3: Did not do)
IMT_U2_F $\in \{1,2,3\}$	#How children carry out U2 in their first attempt (1: Accurate, 2: Inaccurate, 3: Did not do)
IMT_U2_W $\in \{1,2,3\}$	#Children's best carry out of U2 in the whole period (1: Accurate, 2: Inaccurate, 3: Did not do)
IMT_N1_F $\in \{1,2,3\}$	#How children carry out N1 in their first attempt (1: Accurate, 2: Inaccurate, 3: Did not do)
IMT_N1_W $\in \{1,2,3\}$	#Children's best carry out of N1 in the whole period (1: Accurate, 2: Inaccurate, 3: Did not do)
IMT_N2_F $\in \{1,2,3\}$	#How children carry out N2 in their first attempt (1: Accurate, 2: Inaccurate, 3: Did not do)
IMT_N2_W $\in \{1,2,3\}$	#Children's best carry out of N2 in the whole period (1: Accurate, 2: Inaccurate, 3: Did not do)
IMT_act, string	#A sequence of letters (U1U2N1N2CE) corresponding to child's action sequence, end either when they touched the ball/piece (C) or when the toy is taken away U1: unnecessary action1, U2: unnecessary action 2, N1: necessary action 1, N2: necessary action 2, C: touching the ball/piece, D: other actions aiming at getting out the toy E: other actions not aiming at getting out the toy

IMT_strategy ∈ {1,2,3,4} #See below

		Clear box	Monkey box	Prize box
U1	first unnecessary action	Push the bolt Accurate: use tool Inaccurate: use hand to push the bolt from the same end (U1') Inaccurate: use hand to remove the bolt in a different way (U1'') Inaccurate: push the bolt from the other end using the tool (U1*)	Push the bolt Accurate: use tool Inaccurate: use hand to push the bolt from the same end (U1') Inaccurate: use hand to remove the bolt in a different way (U1'') Inaccurate: push the bolt from the other end using the tool (U1*)	Swing arm Accurate: use hand
U2	second unnecessary action	Tap Accurate: tap several times in the hole Inaccurate: tap on wrong surface (U2')	Tap Accurate: tap several times in the hole Inaccurate: tap on wrong surface (U2')	
N1	first necessary action	Open door Accurate: life the door Inaccurate: move the door aside (N1') Inaccurate: move the door/open the lid with stick (N1'')	Open door Accurate: lift the door Inaccurate: lift the door with the stick (N1")	Open door Accurate: open the small lid Inaccurate: push in the small lid in (N1') Inaccurate: open the big lid (N1*) No code if the child insert the stick straight through the lid
N2	second necessary action	Insert stick Accurate: from an open door Inaccurate: insert stick from a different angle (above the door or to the side) (N2'')	Insert stick Inaccurate: use hand (N2') Inaccurate: use the other end (N2*)	Insert stick Inaccurate: Insert stick straight through the lid (N2'') Inaccurate: use hand to reach the ball (N2')

		Inaccurate: use hand (N2’) Inaccurate: use the other end (N2*)		Inaccurate: use the other end (N2*)

Necessary 1: N1, N1’, N2, N2’’, N2*

Sometimes I demonstrated a second time just to help children get the reward, in these cases only children’s response after the first demonstration counts (this is not the case when I demonstrated a second time because children did not pay attention to the first demonstration).

Imitative behavior	1 faithful imitation	Performing the demonstrated actions, no additional actions
	2 selective imitation	Performing only the necessary actions, no additional actions, use
	- 21 selective imitation	imitate all necessary actions accurately (N1N2C)
	- 22 emulation	Imitate at least one necessary action inaccurately (N1N2’C)
	4 faithful + selective	Combination of faithful and selective imitation, same order, no additional actions. Did one of the two Unnecessary actions
	- 41 faithful + selective	Perform one of the two unnecessary actions, imitated all necessary actions accurately (U1N1N2C)
	- 42 faithful + emulation	Perform at least one unnecessary action, imitate at least one necessary action inaccurately (U1N1’N2’C)
	3“Other”	Any other way of retrieval, include 3 subcategories as listed below:
	- 32additional actions	Adding additional actions which were not demonstrated (exploring and experimenting with the toy, E).
	- 33own way	Using a different way to retrieve the piece. (D)
	5 No response	No action relevant to the task

Priority: 33,32,other

MAH: Mouse and House

MAH_HH: House & Hop
MAH_HS: House & Slide
MAH_NH: NoHouse & Hop
MAH_NS: NoHouse & Slide

MAH_complete $\in \{1,2,3,4\}$	#If the child completed the task (1: experimenter did not administrate, 2: child did not participate, 3: child did participate but did not finish, 4: child completed the task)
MAH _distract $\in \mathbb{N}_0$	#Number of time children got distracted during this task (looked away for more than 5 sec when they are supposed to be watching/reacting, e.g., when they give the stimuli to parent and watch parent's reaction)
MAH _time $\in \mathbb{N}_0$	#Amount of time (in second) that children engaged in this task (exclude distracted time)
MAH _respondtime $\in \mathbb{N}_0$	#Amount of time (in second) children played with the mouse (even if not task relevant), starting from baby first touched the mouse to when the mouse is taken away (exclude distracted time)
MAH _style $\in \{1,2,3,9\}$	#3: the same style on the mat (hopping or sliding); 2: the same style but inaccurate (e.g., not on the mat, only one hop); 1: an incorrect style (e.g., hop in a sliding condition). 9: no task-related style Mouse_slide: 3 would be sliding more than half of the distance between the edge of the mat and the house Doggie_slide: 3 would be making at least one turn when sliding (making a circle doesn't count), 2 would be sliding but not making any turns Mouse_hop: 3 would be clearly breaking touch with the mat at least twice. 2 would be subtly breaking touch with the mat at least twice or breaking touch with the mat only once Doggie_hop: 3 would be clearly breaking touch with the mat at least twice. 2 would be subtly breaking touch with the mat at least twice or breaking touch with the mat only once

MAH _sound ∈ {1,2,3,9}	#3: Mouse: the same sound (bebe or beee); 2: any repeated syllables (e.g.'dedede') in the hopping condition or any long, single syllable (e.g. 'teeee') in the sliding condition; 1: an incorrect sound (e.g., beee in the hopping condition); 9: no task-related sound Doggie: (bububu or buuuuuu)
MAH _location ∈ {1,2,3,9}	#House condition—3: put into the correct house, 2: put beside/in front of/put though the correct house, 1: put into the opposite house or somewhere else on the mat, 9: not put on the mat/irrelevant NoHouse condition—3: put to the same location as the experimenter did, 2: put somewhere else on the same side of the mat, 1: put on the opposite side or in the middle, 9: not put on the mat/irrelevant The first location that the child stopped moving the mouse would be considered the location coded here.

CBT : Corsi Block-Tapping Task. The following variables are measured for each participant during each visit:

CBT_complete ∈ {1,2,3,4}	#If the child completed the task (1: experimenter did not administrate, 2: child did not participate, 3: child did participate but did not finish, 4: child completed the task)
CBT_distract ∈ $\mathbb{N}_0$	#Number of time children got distracted during this task (looked away for more than 5 sec when they are supposed to be watching/reacting)
CBT_time ∈ $\mathbb{N}_0$	#Amount of time (in seconds) that children engaged in this task
CBT_span ∈ {2,3,…9}	#The longest length of sequence repeated correctly (wrong order doesn't count)
CBT_total ∈ $\mathbb{N}_0$	#The product of CBT_span and the number of correct trials (e.g., if the child did 2,2,3 right and did not do the rest right, the total would be 2*2+1*3 = 7)

GST : Grass and Snow Task. The following variables are measured for each participant during each visit:

GST_complete $\in \{1,2,3,4\}$	#If the child completed the task (1: experimenter did not administrate, 2: child did not participate, 3: child did participate but did not finish, 4: child completed the task)
GST_distract $\in \mathbb{N}_0$	#Number of time children got distracted during this task (looked away for more than 5 sec when they are supposed to be watching/reacting)
GST_time $\in \mathbb{N}_0$	#Amount of time (in second) that children engaged in this task
GST_testtrials $\in \{1,2,3,\ldots 8\}$	#The number of trials tested (grass is 1 trial, snow is 1 trial)
GST_correcttrials $\in \{1,2,3,\ldots 8\}$	#The number of trials children give the right answer

ToM: Theory-of-Mind Task. The following variables are measured for each participant during each visit:

ToM _complete $\in \{1,2,3,4\}$	#If the child completed the task (1: experimenter did not administrate, 2: child did not participate, 3: child did participate but did not finish, 4: child completed the task)
ToM _distract $\in \mathbb{N}_0$	#Number of time children got distracted during this task (looked away for more than 5 sec when they are supposed to be watching/reacting)
ToM_time $\in \mathbb{N}_0$	#Amount of time (in second) that children engaged in this task
ToM _diversedesire $\in \{1,2,3,4\}$	#Child's reaction for Diverse Desire task, 1: other's desire; 2: own desire; 3: no answer; 4: don't know.
ToM _diversebelief $\in \{1,2,3,4\}$	#Child's reaction for Diverse Belief task, 1: other's belief; 2: own belief; 3: no answer; 4: don't know; .
ToM _KAtarget $\in \{1,2,3,4\}$	#Child's reaction for the target question (know) in the Knowledge Access task, 1: no; 2: yes; 3: no answer; 4: don't know; 5: "piggy".
ToM _KAcontrol $\in \{1,2,3,4\}$	#Child's reaction for the control question (see) in the Knowledge Access task, 1: no; 2: yes; 3: no answer; 4: don't know; 5: "piggy".

WL: Word Learning Task

WL_complete ∈ {1,2,3,4}	#If the child completed the task (1: experimenter did not administrate, 2: child did not participate, 3: child did participate but did not finish (including the case when children did not answer at least 1 question), 4: child completed the task)
WL_distract ∈ $\mathbb{N}_0$	#Number of time children got distracted during this task (looked away for more than 5 sec when they are supposed to be watching/reacting)
WL_time ∈ $\mathbb{N}_0$	#Amount of time (in second) that children engaged in this task (exclude distracted time), including the time children watch demonstration, play with the toy and respond to questions
WL_word_initial ∈ {1,2,3,4,9}	#1: same; 2: different; 3: both; 4: no answer; 9: wasn't asked
WL_ word_initial_RT ∈ $\mathbb{N}_0$	#Amount of time (in second) that children responded to the question
WL_word_general ∈ {1,2,3,4,9}	#1: same; 2: different; 3: both; 4: no answer; 9: wasn't asked
WL_word_general_RT ∈ $\mathbb{N}_0$	#Amount of time (in second) that children responded to the question
WL_word_mutualex ∈ {1,2,3,4,9}	#1: correct; 2: incorrect; 3: both; 4: no answer; 9: wasn't asked
WL_word_mutualex_RT ∈ $\mathbb{N}_0$	#Amount of time (in second) that children responded to the question
WL_prefer_initial ∈ {1,2,3,4,9}	#1: same; 2: different; 3: both; 4: no answer; 9: wasn't asked
WL_prefer_initial_RT ∈ $\mathbb{N}_0$	#Amount of time (in second) that children responded to the question
WL_ prefer_general ∈ {1,2,3,4,9}	#1: same; 2: different; 3: both; 4: no answer; 9: wasn't asked
WL_ prefer_general_RT ∈ $\mathbb{N}_0$	#Amount of time (in second) that children responded to the question

AF: Artifact Function Task

AF_complete ∈ {1,2,3,4}	#If the child completed the task (1: experimenter did not administrate, 2: child did not participate, 3:

	child did participate but did not finish (including the case when children did not answer at least 1 question), 4: child completed the task)
AF_distract $\in \mathbb{N}_0$	#Number of time children got distracted during this task (looked away for more than 5 sec when they are supposed to be watching/reacting, not when I was switching toys)
AF_time $\in \mathbb{N}_0$	#Amount of time (in second) that children engaged in this task (exclude distracted time)
AF_first $\in \{1,2,3,4,9\}$	#1: correct; 2: incorrect; 3: hand; 4: no response; 9: wasn't asked (if children used multiple tools, use their first response. If they used both hand and tools, use the first tool they use)
AF_first_RT $\in \mathbb{N}_0$	#Amount of time (in second) that children responded to the question
AF_second $\in \{1,2,3,4,9\}$	#1: correct; 2: incorrect; 3: hand; 4: no response; 9: wasn't asked (if children used multiple tools, use their first response. If they used both hand and tools, use the first tool they use)
AF_second_RT $\in \mathbb{N}_0$	#Amount of time (in second) that children responded to the question

ST: Sorting

ST_complete $\in \{1,2,3,4\}$	#If the child completed the task (1: experimenter did not administrate, 2: child did not participate, 3: child did participate but did not finish, 4: child completed the task)
ST_distract $\in \mathbb{N}_0$	#Number of time children got distracted during this task (looked away for more than 5 sec when they are supposed to be watching/reacting, not when I was switching toys)
ST_time $\in \mathbb{N}_0$	#Amount of time (in second) that children engaged in this task (exclude distracted time)
ST_color_strategy $\in \{1,\ldots 4\}$	#Child's sorting strategy (1: color, 2: sound, 3: all in one box, 4: other)

ST_color_correct ∈ {1,2,3}	#If children sorted the objects according to the same color/sound as the experimenter did (1:correct, 2: reverse, 3:not applicable)
ST_color_shaking ∈ {1,…4}	#number of toys shaken
ST_color_RT $\in \mathbb{N}_0$	#Amount of time (in second) that children responded to the question
ST_sound_strategy ∈ {1,…4}	#Child's sorting strategy (1: color, 2: sound, 3: all in one box, 4: other)
ST_sound_correct ∈ {1,2,3}	#If children sorted the objects according to the same color/sound as the experimenter did (1:correct, 2:incorrect, 3:not applicable)
ST_sound_shaking ∈ {1,…4}	#number of toys shaken
ST_sound_RT $\in \mathbb{N}_0$	#Amount of time (in second) that children responded to the question
ST_mix_strategy ∈ {1,…4}	#Child's sorting strategy (1: color, 2: sound, 3: all in one box, 4: other)
ST_mix_correct ∈ {1,2,3}	#If children sorted the objects according to the same color/sound as the experimenter did (1:correct, 2:incorrect, 3:not applicable)
ST_mix_shaking ∈ {1,…4}	#number of toys shaken
ST_mix_RT $\in \mathbb{N}_0$	#Amount of time (in second) that children responded to the question
ST_vocal imitation $\in \mathbb{N}_0$	Total number of times children imitate the experiments' sentences ("This one goes here/there")

TVW: "There" vs. "Whoops" Task

TVW_complete ∈ {1,2,3,4}	#If the child completed the task (1: experimenter did not administrate, 2: child did not participate, 3: child did participate but did not finish, 4: child completed the task)
TVW_distract $\in \mathbb{N}_0$	#Number of time children got distracted during this task (looked away for more than 5 sec when they are supposed to be watching/reacting, not when I was switching toys)
TVW_time $\in \mathbb{N}_0$	#Amount of time (in second) that children engaged in this task (exclude distracted time)

TVW_Toy1 ∈ {1,2,3,4,5,6}	The first toy (1: Yellow, 2: Purple, 3: Blue, 4: Green, 5: Orange, 6: Pink)
TVW_Toy1_Act1 ∈ {1,2}	The first action of the experimenter (1: "There", 2: "Whoops")
TVW_Toy1_Response1 ∈ {1,2}	The first response of the child (1: "There" action, 2: "Whoops" action)
TVW_Toy1_TotThere ∈ $\mathbb{N}_0$	Total number of "There" actions children did
TVW_Toy1_TotWhoops ∈ $\mathbb{N}_0$	Total number of "Whoops" actions children did
TVW_Toy2 ∈ {1,2,3,4,5,6}	The second toy (1: Yellow, 2: Purple, 3: Blue, 4: Green, 5: Orange, 6: Pink)
TVW_Toy2_Act1 ∈ {1,2}	The first action of the experimenter (1: "There", 2: "Whoops")
TVW_Toy2_Response1 ∈ {1,2}	The first response of the child (1: "There" action, 2: "Whoops" action)
TVW_Toy2_TotThere ∈ $\mathbb{N}_0$	Total number of "There" actions children did
TVW_Toy2_TotWhoops ∈ $\mathbb{N}_0$	Total number of "Whoops" actions children did\
TVW_vocal imitation ∈ $\mathbb{N}_0$	Total number of times children imitate the experiments' vocalization ("There" and "Whoops")

SH: sharing

SH_complete ∈ {1,2,3,4}	#If the child completed the task (1: experimenter did not administrate, 2: child did not participate, 3: child did participate but did not finish, 4: child completed the task)
SH_distract ∈ $\mathbb{N}_0$	#Number of time children got distracted during this task (looked away for more than 5 sec when they are supposed to be watching/reacting, not when I was switching toys)
SH_time ∈ $\mathbb{N}_0$	#Amount of time (in second) that children engaged in this task (exclude distracted time)
SH_shareddoggie ∈ {1,…5}	#number of stickers shared with doggie (put in doggie's box or put on doggie), till when I moved the box away
SH_sharedother ∈ {1,…5}	#number of stickers shared with other people (mom, sibling, experimenter, etc.), till when I moved the box away

DQ: Demographic Questionnaire. The following variables are measured for each participant during their first visit:

DQ.sex ∈ {"M","F"} #The child's sex

DQ.race ∈ {"Caucasian", "Hispanic", "African", "Asian", "Mixed", "Other"} #The child's race

DQ.edu1 ∈ {1,2,3,4} #Major caregiver's education level (1 for grade school and under, 4 for graduate/professional)

DQ.edu2 ∈ {1,2,3,4} #Second caregiver's education level (1 for grade school and under, 4 for graduate/professional)

DQ.income ∈ {1,2,3,4} #Annual family income (1 for < $20,000, 4 for > $100,000)

DQ.oldsib ∈ $\mathbb{N}_0$ #Number of the child's older siblings

The following variables are measured for each participant during each visit:

DQ.age ∈ [22,50] #The child's actual age in month at the visit

DQ.youngsib ∈ $\mathbb{N}_0$ #Number of the child's younger siblings

DQ.daycarelength ∈ [0,50] #Number of months that the child had spent in day care/preschool till the visit

DQ.daycarefeq ∈ [0,168] #Number of hours the child spent in day care/preschool per week

DQ.daycareadj ∈ [0,280] #Adjusted number of months children had spent in day care/preschool (based on 30 hours/week)

DQ.daycaretotal = DQ.daycarelength * DQ.daycarefeq / 30

GDS: General Development Scale from Child Development Inventory. The following variable is measured for each participant during each visit:

GDS.total ∈ {0,1,…70} #Total score of GDS

CDI2: MacArthur Communicative Development Inventories-Level II Form B. The following variable is measured for each participant during their first and second visit:

CDI2.vocabulary ∈ {0,1,…75} #Total number of word on the list that the child says

CDI3: MacArthur Communicative Development Inventories-Level III. The following variables are measured for each participant during their second and third visit:

CDI3.vocabulary ∈ {0,1,…100} #Total number of word on the list that the child says

CDI3.grammar ∈ {0,1,…12} #Total number of sentence pairs on the list that the child manages

ECBQ: Early Childhood Behavior Questionnaire. The following variables are measured for each participant during their first and second visit:

ECBQ. negativeaffectivity $\in [0,7]$ #Summery score for the factor "Negative Affectivity"
ECBQ.surgencyextraversion $\in [0,7]$ #Summery score for the factor "Surgency/Extraversion"
ECBQ.effortfulcontrol $\in [0,7]$ #Summery score for the factor "Effortful Control"

CBQ: Child's Behavior Questionnaire. The following variables are measured for each participant during their third and fourth visit:
CBQ. negativeaffectivity $\in [0,7]$ #Summery score for the factor "Negative Affectivity"
CBQ.surgencyextraversion $\in [0,7]$ #Summery score for the factor "Surgency/Extraversion"
CBQ.effortfulcontrol $\in [0,7]$ #Summery score for the factor "Effortful Control"

Appendix 2. Algorisms used to compute children's language and temperament scores

Language score was calculated in the following ways:

1. I computed logit score for children's CDI2 and CDI3 scores. To avoid invalid computation for children who scored 0 or 100, I added 1 to all scores and divided them by 102.

   $L2 = \ln[(CDI2 + 1)/(101-CDI2)]$

   $L3 = \ln[(CDI3 + 1)/(101-CDI3)]$

2. I computed the average difference between L2 and L3 for visits in which parents filled out both CDI2 and CDI3 (when their child is 30 months of age).

   D = Mean (L3-L2), for all visits in which both CDI2 and CDI3 had been filled.

   The result is D = 0.69, SD(D) = 0.34

3. For visits in which only CDI2 was filled out, I used the logit score for CDI2 as their language score, L = L2. For visits in which only CDI3 was filled out, I used the logit score for CDI3 minus the average difference (D) as their language score, L = L3 - D. For visits in which both CDI2 and CDI3 were filled out, I used the average of L2 and L3 - D as their language score, L = (L2 + L3 - D)/2.

Temperament score was calculated in the following ways:

1. For each subscale, I computed the average difference between ECBQ and CBQ for visits in which parents filled out both ECBQ and CBQ (when their child is 36 months

of age).

$D_{negative\ affectivity}$ = Mean ($CBQ_{negative\ affectivity}$ - $ECBQ_{negative\ affectivity}$),

$D_{surgency}$ = Mean ($CBQ_{surgency}$ - $ECBQ_{surgency}$),

$D_{effortful\ control}$ = Mean ($CBQ_{effortful\ control}$ - $ECBQ_{effortful\ control}$),

for all visits in which both CDI2 and CDI3 had been filled.

The result is $D_{negative\ affectivity}$ = 0.79, SD ($D_{negative\ affectivity}$) = 0.79,

$D_{surgency}$ = -0.97, SD ($D_{surgency}$) = 0.65,

$D_{effortful\ control}$ = 0.29, SD ($D_{effortful\ control}$) = 0.54.

2. For visits in which only ECBQ was filled out, I used the ECBQ scores as their temperament score, Negative affectivity = $ECBQ_{negative\ affectivity}$, Surgency = $ECBQ_{surgency}$, Effortful control = $ECBQ_{effortful\ control}$. For visits in which only CBQ was filled out, I used CBQ minus the average difference (D) as their temparement score, Negative affectivity = $CBQ_{negative\ affectivity}$ - $D_{negative\ affectivity}$, Surgency = $ECBQ_{surgency}$ - $D_{surgency}$, Effortful control = $ECBQ_{effortful\ control}$ - $D_{effortful\ control}$. For visits in which both CDI2 and CDI3 were filled out, I used the average of ECBQ and CBQ - D as their temperament score.

Appendix 3. Mixed-model regression analysis

I used mixed models to examine the effect of age and visit on the outcome measurements.

The Model:

$Y_{ij} = \beta 0 + \beta 1T1_{ij} + \beta 2T3_{ij} + \beta 3T4_{ij} + \beta 4j + r_i + e_{ij}$, i(participant)=1,2…48, j(visit)=1,2,3

Y_{ij} is the outcome measurement for child I's jth visit

β0 is the interception

$T1_{ij}$ = {1,0,0,0} for 24, 30, 36 and 42 months of age during child i's jth visit, if β1 < 0 then 30-month-old children is higher on the outcome measurement than 24-month-old children

$T3_{ij}$ = {0,0,1,0} for 24, 30, 36 and 42 months of age during child i's jth visit, if β2 > 0 then 36-month-old children is higher on the outcome measurement than 30-month-old children

$T4_{ij}$ = {0,0,0,1} for 24, 30, 36 and 42 months of age during child i's jth visit, if β3 > 0 then 42-month-old children is higher on the outcome measurement than 30-month-old children

If β4 > 0 then there is practice effect

r_i is the random effect of the participant

e_{ij} is the error term