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The ontogeny of cumulative culture: Individual toddlers vary in faithful imitation and goal emulation

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Abstract

The success of human culture depends on early emerging mechanisms of social learning, which include the ability to acquire opaque cultural knowledge through faithful imitation, as well as the ability to advance culture through flexible discovery of new means to goal attainment. This study explores whether this mixture of faithful imitation and goal emulation is based in part on individual differences which emerge early in ontogeny. Experimental measurements and parental reports were collected for a group of 2-year-old children (N = 48, age = 23–32 months) on their imitative behavior as well as other aspects of cognitive and social development. Results revealed individual differences in children's imitative behavior across trials and tasks which were best characterized by a model that included two behavioral routines; one corresponding to faithful imitation, and one to goal emulation. Moreover, individual differences in faithful imitation and goal emulation were correlated with individual differences in theory of mind, prosocial behavior, and temperament. These findings were discussed in terms of their implications for understanding the mechanisms of social learning, ontogeny of cumulative culture, and the benefit of analyzing individual differences for developmental experiments.

KEYWORDS

confirmatory factor analysis, faithful imitation, goal emulation, individual differences, principle component analysis, social learning

1 | INTRODUCTION

The success of humans has been attributed to our species' unique capacity to build "cumulative culture": to accumulate knowledge, skills, and conventions over generations through social learning (Boyd, Richerson, & Henrich, 2011; Caldwell & Millen, 2008; Dean, Vale, Laland, Flynn, & Kendal, 2014; Kurzban & Barrett, 2012; Tomasello, Kruger, & Ratner, 1993). Building cumulative culture requires a balance between faithful transmission and occasional innovation, as illustrated in the "ratchet effect" (Tennie, Call, & Tomasello, 2009): On one hand, faithful cultural transmission can work as a "ratchet" to prevent slippage backward, so that techniques or practices can be passed on over generations (Boyd & Richerson, 1985). On the other hand, innovation could help develop more advanced techniques or practices to address the problems more efficiently (Lehmann, Feldman, & Kaeuffer, 2010).

Research in comparative psychology has identified different patterns of imitative behaviors that may serve as proximate mechanisms underlying transmission and innovation in individual agents (Hoppitt & Laland, 2013). "Faithful imitation" refers to copying the exact form of an action or a sequence of actions, with or without being aware of the goal behind it (Whiten & Ham, 1992). The focus on reproducing the form ensures that the techniques or practices are transmitted with high fidelity. In contrast, "goal emulation" refers to copying the overarching goal behind an action or a sequence of actions, with or without applying the exact same method (D. Wood, 1989). The focus on reproducing the goal leaves room for modifying existing techniques or practices to more (or less) efficient versions, therefore goal emulation and innovation shares the important requirement of cognitive flexibility during goal attainment (Carr, Kendal, & Flynn, 2016).[1]

The transmission–innovation balance can be achieved by variations in social learning both within and across individuals. Individual learners can, and do, switch between faithful imitation and goal emulation based on factors such as prior experiences, task complexity, relative costs of social and asocial learning, consensus among the social group, and levels of temporal and spatial variation in the environment (Morgan, Rendell, Ehn, Hoppitt, & Laland, 2012; Williamson & Meltzoff, 2011; Williamson, Meltzoff, & Markman, 2008). The aggregation of these individual choices, given proper environmental constraints, has been shown to lead to cumulative cultural evolution (Boyd & Richerson, 1996; Kameda & Nakanishi, 2003). But also, the balance can happen across individuals (Thornton & Lukas, 2012): When facing a same task at the same time, some individuals in the social group could routinely imitate traditional methods, when others routinely emulate and innovate (Efferson, Lalive, Richerson, McElreath, & Lubell, 2008). This leaves open the bases of individuals' different tendencies to either copy the form of actions or copy the goal—it could be based on their own preferences (Toelch, Bruce, Newson, Richerson, & Reader, 2014), cognitive capacities (Muthukrishna, Morgan, & Henrich, 2016), or their position in the social group (Cook, den Ouden, Heyes, & Cools, 2014). Regardless, the social group as a whole can benefit from this division of labor (Mesoudi, Chang, Dall, & Thornton, 2016).

Research in child development has offered much insight into the ontogeny of cumulative culture in general (Dean, Kendal, Schapiro, Thierry, & Laland, 2012; Flynn & Whiten, 2012), and the transmission–innovation balance in particular (Legare & Nielsen, 2015; McGuigan et al., 2017; Rawlings, Flynn, & Kendal, 2016; Tennie, Walter, Gampe, Carpenter, & Tomasello, 2014). Indeed, substantial evidence has suggested that both the tendency to copy the form of an action and to copy its goal have roots early in life (Meltzoff, 1988; Over & Carpenter, 2012; Užgiris, 1981; Want & Harris, 2002). A fast-growing literature has documented that after young children watch an adult demonstrating a sequence of actions on an artifact, they tend to "overimitate"[2]—to faithfully copy all actions even when some appear inefficient or irrelevant (Hoehl et al., 2019; Horner & Whiten, 2005; Lyons, Young, & Keil, 2007). In other lines of research, however, infants and children have also demonstrated the ability to flexibly modify socially demonstrated actions, for example by selectively copying those that are goal-directed or causally relevant (Carpenter, Akhtar, & Tomasello, 1998; DiYanni & Kelemen, 2008; Williamson et al., 2008), or deviate to produce novel solutions to the same goal (Carr, Kendal, & Flynn, 2015; Neldner et al., 2019). Indeed, many environmental factors have been shown to influence how faithfully children imitate, including the causal opacity of the artifact (Buchsbaum, Gopnik, Griffiths, & Shafto, 2011; Lyons, Damrosch, Lin, Macris, & Keil, 2011), the characteristics of the model (Nielsen & Blank, 2011; Wilks, Collier-Baker, & Nielsen, 2014), and the relevance of the actions to the immediate context (Clegg & Legare, 2016b; Yu & Kushnir, 2014). These variations in children's imitative behavior may have important implications for cumulating culture. When groups of preschool-aged children are introduced to a novel puzzle box, the combination of different social learning strategies has been shown to contribute to both the transmission and the evolution of "microcultures" within each group (McGuigan et al., 2017; Whiten & Flynn, 2010).

Research Highlights

- Individual differences are found in children's social learning behavior.
- They are characterized by tendencies of faithful imitation and goal emulation.
- They correlate with theory of mind, prosocial behavior, and temperament.
- They may serve as a basis for human cumulative culture.

We know much less, however, about whether the transmission–innovation balance could also characterize an individual difference. Previous studies have used a range of methods to assess social learning and imitation in groups of children across different contexts. Thus, it is unknown whether these methods, developed to capture variation across contexts rather than individuals, converge to capture consistent individual differences between children. This study aims to address this gap by measuring children's behavior across a battery of imitation tasks taken from previous research (Brugger, Lariviere, Mumme, & Bushnell, 2007; Carpenter, Call, & Tomasello, 2005; Horner & Whiten, 2005; Lyons et al., 2011; Nielsen, Moore, & Mohamedally, 2012; Yu & Kushnir, 2014), and by analyzing individual differences in terms of faithful imitation and goal emulation.

Importantly, we also explore the relation between imitative behavior and young children's emerging cognitive and social skills. Prior research points to the fact that in the first few years of life, children develop inferential capacities to interpret different social learning contexts, and learn accordingly (Csibra & Gergely, 2006; Meltzoff, 2007; Over & Carpenter, 2012). Thus, we reason that individual differences in the ease with which children make the appropriate inferences (e.g., due to differences in knowledge, experience, or general cognitive and social abilities) might contribute to individual differences in imitative behavior.

One candidate contributor is children's knowledge of physical artifacts and physical causality (DiYanni & Kelemen, 2008). Research has shown that children are more likely to copy acts that achieve desired causal outcomes (Brugger et al., 2007; Buchsbaum et al., 2011; Evans, Laland, Carpenter, & Kendal, 2018; Williamson et al., 2008), and they copy with higher fidelity when causal mechanisms are opaque rather than transparent (Horner & Whiten, 2005; Wilks, Kapitány, & Nielsen, 2016). Similarly, developmental changes in artifact knowledge contribute to changes in imitative behavior: older children are more likely than younger children to reject tool choices that are not functional (DiYanni & Kelemen, 2008). Even for children of the same age, experimentally manipulating individual children's knowledge about and experience with particular artifacts influences their imitative behavior (Williamson et al., 2008; L. A. Wood, Kendal, & Flynn, 2013). Together, these studies point to a potential individual difference: namely that individual children who are better at learning physical causality would be focusing more on achieving the final goal of the demonstrator, without necessarily applying the identical means.

A second candidate source of individual variation regards children's social cognition—specifically their ability to infer others' goals. Research has shown that infants and young children are more likely to reproduce intentional actions as compared to failed actions (Meltzoff, 1995), accidental actions (Carpenter et al., 1998), or actions that are forced by environmental constraints (Gergely, Bekkering, & Király, 2002). They also adjust response to a demonstration based on the demonstrator's overarching goal shown before or after the demonstration (Carpenter, Call, & Tomasello, 2002; Southgate, Chevallier, & Csibra, 2009; Williamson & Markman, 2006; Yu & Kushnir, 2014). Notably, children also understand that goals are organized hierarchically, and imitate accordingly (Keupp, Behne, & Rakoczy, 2018). When an action has a clear external goal, children infer that the demonstrator has an instrumental intention (such as to complete a task), and focus on re-enacting the external goal during their turn of imitation (Meltzoff, 1995). In contrast, when an action lacks a clear external goal, children infer that the demonstrator has a pedagogical intention (such as to show how an action should be performed), and focus on reproducing the exact manner of the action (Bekkering, Wohlschlager, & Gattis, 2000; Carpenter et al., 2005; Gleissner, Bekkering, & Meltzoff, 2000). This body of literature predicts a link between children's social cognitive skill and their tendency to flexibly emulate based on the demonstrator's intention. Moreover, previous research has revealed remarkable individual differences in children's social cognition about human actions (Dunn, Brown, Slomkowski, Tesla, & Youngblade, 1991), and such individual differences may be stable from infancy to preschool years (Brooks & Meltzoff, 2015; Wellman, Lopez-Duran, LaBounty, & Hamilton, 2008). In this study, we explore whether individual differences in social cognition are also reflected in individual differences in goal emulation. That is, whether children who are better at reading others' intentions are more apt to infer, and thus emulate, the demonstrator's goal.

A third candidate source of individual variation is motivational, specifically the motivation for social affiliation (Nielsen, 2008; Over & Carpenter, 2013). A number of studies have shown that children's tendencies to imitate increases with the need to affiliate with the model. For example, preschoolers imitate more after watching a live rather than televised demonstration (McGuigan, Whiten, Flynn, & Horner, 2007; Nielsen, Simcock, & Jenkins, 2008). They also imitate more when the model is present during their turn (Nielsen & Blank, 2011), when the model is socially communicative (Hoehl, Zettersten, Schleihauf, Grätz, & Pauen, 2014; Nielsen, 2006; Schleihauf, Graetz, Pauen, & Hoehl, 2018), when the model is an in-group member (Buttelmann, Zmyj, Daum, & Carpenter, 2013; Gruber, Deschenaux, Frick, & Clément, 2019), and when primed with ostracism (Over & Carpenter, 2009; Watson-Jones, Legare, Whitehouse, & Clegg, 2014; Watson-Jones, Whitehouse, & Legare, 2016). The affiliative 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; Eckerman, Davis, & Didow, 1989), or as a response toward parental socialization (Forman & Kochanska, 2001). Moreover, the tendency to "overimitate" has been associated with individual differences in children's social affiliation motives: Typically developing children and children with William syndrome have been shown to imitate more faithfully than children with Autism Spectrum Disorder (Marsh, Pearson, Ropar, & Hamilton, 2013; Nielsen, Slaughter, & Dissanayake, 2013; Vivanti, Hocking, Fanning, & Dissanayake, 2017), and 15-month-old infants who were rated high on extraversion imitated more faithfully than those who were rated low (Hilbrink, Sakkalou, Ellis-Davies, Fowler, & Gattis, 2013). In this study, we explore whether individual rates of faithful imitation are related to both their affiliative traits (measured by parental report) and affiliative behaviors (measured by experimental tasks).

Finally, research has linked the tendency to imitate faithfully with children's normative reasoning (Clegg & Legare, 2016b; Kenward, Karlsson, & Persson, 2011; Keupp, Behne, & Rakoczy, 2013). It has been shown that children, especially in the preschool years, often copy the unnecessary means because they view those as prescriptive norms: They protest when a third party omits unnecessary actions, often using normative language (Kenward, 2012; Keupp et al., 2013; Keupp, Behne, Zachow, Kasbohm, & Rakoczy, 2015); they imitate more when the task is described as a convention (Clegg & Legare, 2016a, 2016b), and they differentiate between ritualistic and instrumental actions (Liberman, Kinzler, & Woodward, 2018; Nielsen, Tomaselli, & Kapitány, 2018). This line of research leads to the suggestion that children who tend to be norm-focused, and thus view demonstrations as an indication of conventions or rituals, may be more likely to imitate faithfully.

In sum, previous research suggests that individual children may differ in faithful imitation and goal emulation, and that these individual differences may relate to their developing causal knowledge, social cognition, affiliative motivation, and normative reasoning. In this study, we systematically investigate the individual differences in imitative behavior in a group of 2-year-olds, and examine their relation to other aspects of development. We chose 2-year-olds because previous studies suggested a mixture of imitation and emulation on average at this age, as well as large amounts of behavioral variation across even the same types of tasks (McGuigan & Whiten, 2009; Yu & Kushnir, 2014). By testing this group of children, we aim to address three research questions: (a) Do children show individual differences in imitative behavior, which is consistent across different trials and tasks? (b) Can these variations be further characterized by how much children imitate faithfully and emulate the model's goal? and (c) Do children's tendencies of faithful imitation and goal emulation relate to their causal knowledge, social cognition, affiliative motivation, and normative reasoning?

TABLE 1 Comparisons between the three sets of puzzle boxes used in the study

	First set			Second set			Third set		
Original study	**Brugger et al. (2007); Yu and Kushnir (2014)**			**Nielsen et al. (2012)**			**Horner and Whiten (2005)**	**Lyons et al. (2011)**	
Name	Ramp	Rake	Flowerbox	Blue box	Switch box	Artificial fruit	Clear box	Monkey box	Prize box
First unnecessary action	Remove barrier	Cover hole	Remove velcro latch	Place red stick on top of box and wipe around three times	Tap mallet on top of box three times	Wipe blue stick along box from back to front three times	Push the bolt with stick	Push the bolt with stick	Swing arm with hand
Second unnecessary action	—	—	—	—	—	—	Insert stick in box and tap three times	Insert stick in box and tap three times	—
First necessary action	Push the reward with a pusher	Pull out a T-shaped paddle	Pull open the lid	Hold stick on top of knob, push down, and in so doing open front of box	Using mallet, push switch from left to right to open box	Using blue stick, push out dowels toward front until they fall onto top of table	Lift door with hand	Lift door with hand	Open lid with hand
Second necessary action	—	—	—	—	—	—	Insert stick to retrieve reward	Insert stick to retrieve reward	Insert stick to retrieve reward
Reward	Puzzle piece	Puzzle piece	Puzzle piece	Bell toy	Castanet	Toy monkey	Puzzle piece	Ball	Ball
Size	Small	Small	Small	Small	Small	Small	Large	Large	Large
Causal complexity	Low	Low	Low	Low	Low	Low	High	High	High
Notes	Unnecessary actions are instrumental; unnecessary actions and necessary actions applied on the same surface of the box; all actions demonstrated with hand. Originally used with infants and preschoolers (14–60 month).			Unnecessary actions are ritualistic; unnecessary actions and necessary actions applied on different surfaces of the box; all actions demonstrated with tool. Originally used with preschoolers (44–50 month).			Unnecessary actions are instrumental; unnecessary actions and necessary actions applied on different surfaces of the box; actions demonstrated with both tool and hand. Originally used with preschoolers (3–5 year).		

To examine the first research question, we included a battery of imitation tasks, broadly divided into two categories: In the "puzzle box" tasks (e.g., Horner & Whiten, 2005), an experimenter demonstrated a series of actions that are either causally necessary or unnecessary for achieving the ultimate goal of retrieving a prize from the box, and we measured how many of the demonstrated actions children reproduced during their turn. As shown in Table 1 and Figure S1, we duplicated three sets of puzzle boxes used by four research groups in previous studies (Brugger et al., 2007; Horner & Whiten, 2005; Lyons et al., 2011; Nielsen et al., 2012), which differed in various factors including causal complexity and the number of necessary and unnecessary actions. Correlations in children's imitation of necessary and unnecessary actions across these three sets of boxes would indicate consistency in individual differences. In the "puppet show" task (Carpenter et al., 2005), the experimenter moved a puppet to either a cardboard house (house condition) or a corresponding location without a house (no house condition), and heperformed the action in a particular manner (a distinct action style accompanied with sound). This task was originally designed to test children's understandings of intentional actions based on whether the action features an external goal (the house). In our study, we measured how much children copied the manner of the puppet shows as an indicator of faithful imitation, and examined how they copied flexibly based on the conditions as an indicator of goal emulation. We further predict that individual differences in children's imitation transcends immediate contextual influences. Thus, even though the puzzle box task features a physical reward and the puppet show task does not, we predict children's behavior to correlate across the two tasks.

The second research question asks whether the individual differences are not only consistent across tasks, but also systematic: We explore whether children vary in how much they faithfully imitate the exact means of the experimenter, and how much they flexibly emulate according to the overarching goals. If variations in imitative behavior are indeed characterized by faithful imitation and goal emulation, we should see measurements of faithful imitation cluster onto one factor, and measurements of goal emulation cluster onto another factor. We examined this hypothesis by submitting individual children's behavior across all measurements into a principle component analysis (PCA). Furthermore, we compared the fit of our faithful imitation-goal emulation model with that of alternative models using confirmatory factor analyses (CFAs). These alternative models assume different factor structures to underlie the observed variations, such as one general factor of copying, or two factors along different lines.

If the factors of faithful imitation and goal emulation can be confirmed, we will further examine the third research question—the correlations between these two factors and other aspects of cognitive and social development. To do this, we included a range of tasks adapted from previously validated experimental procedures that suit 2-year-olds. Children's causal learning properties were measured by a sorting task in which they learn to categorize objects with regard to causal properties that are either obvious or non-obvious (Williamson, Jaswal, & Meltzoff, 2010; Yu & Kushnir, 2016). Children's social cognition was measured using items taken from Wellman and Liu's (2004) Theory-of-Mind Scale. Children's affiliative behavior was measured by a sharing task (Chernyak & Kushnir, 2013), and social affiliation as a trait was assessed by parental report of children's temperament (Putnam, Gartstein, & Rothbart, 2006). Children's normative reasoning was measured by tasks assessing their understanding of the conventionality of object labels (Henderson & Graham, 2005) and artifact functions (Casler & Kelemen, 2007). In addition, children's age, developmental level (i.e., achievements of developmental milestones), and language skills were measured from parental report and used as control variables (Fenson et al., 2000; Ireton, 1992). We hypothesize that individual children's tendency of faithful imitation is related to their affiliative motivation and normative reasoning, and that their tendency of goal emulation is related to their knowledge about artifacts and social cognition.

2 | METHOD

2.1 | Participants

Participants were forty-eight 2-year-olds (21 boys, M_{age} = 26 months, range = 23–32 months) recruited from a small town in upstate NY. One additional child was tested but excluded from the analysis because she did not understand English. According to parental report, 79% of the included children were Caucasian, 98% of their primary caregivers had a college diploma or higher, 85% of their families had an annual household income>$50,000, and 88% of the children were born full-term. One child had been previously diagnosed with benign external hydrocephalus, and another child was diagnosed with language delay at the time of testing. We did not exclude these children because of a lack of direct evidence suggesting imitative behavior is influenced by these developmental delays, but excluding them will not cause qualitative change to any of the findings (see Supporting Information). Children received stickers for their participation, and their parents received $10.

2.2 | Experimental measurements

The same male experimenter (E1, who was not blind to the hypothesis of the study) and one of eight assistants (E2, who was blind to the hypothesis of the study) conducted all experiments. Children first warmed up with E1, E2, and their parents in a laboratory corridor filled with toys. After the children felt comfortable, they were introduced to a playroom where all testing took place. E1 sat facing children across a table for all tasks except for the third set of puzzle box task, which took place on the floor away from the table. The accompanying parents sat next to their children in a separate chair, and were instructed to remain neutral. All experiments were videotaped.

Children completed seven tasks in a fixed order. A fixed order is a standard practice in individual-differences research, because to identify individual differences it is critical to expose all participants to identical experimental contexts (see Carlson & Moses, 2001). To reduce possible carryover effects between tasks, we interspersed tasks that measured the same set of abilities. The tasks were administered in the order presented below. Children were allowed to take breaks and play in the corridor when they showed signs of inattention or fatigue. Twenty children (42%) took one break during the testing session; two (4%) took two breaks; and the rest (54%) completed the testing session without taking a break. The total testing time (not including warm-up and breaks) ranged from 23 to 42 minutes, with a mean of 30 minutes and a standard deviation of 5 minutes.

Children's responses were videotaped and coded by eight coders. Six coders who were blind to the hypothesis of the study served as the main coder for each of the seven tasks (each coder was responsible for one task, except for one coder who was responsible for both the Word Learning and the Artifact Function tasks). Two additional coders served as reliability coders who coded videos from 10 children (21% of all children), and the inter-rater reliabilities are reported for each of the tasks below.

2.2.1 | Puzzle box task

This task evaluated children's imitative behavior after watching a demonstration with an instrumental goal (to retrieve a reward). Three sets of puzzle boxes were built according to designs used in previous studies (Brugger et al., 2007; Horner & Whiten, 2005; Lyons et al., 2011; Nielsen et al., 2012), and each box contained a reward. These boxes were different with regard to size, causal complexity, number of necessary and unnecessary actions, and whether the demonstrated actions were performed with hand or with tools (details see Table 1, and photographs see Figure S1). Each child played with three puzzle boxes, one from each set. These three trials were interspersed throughout the whole testing session. For each trial, E1 presented one of the puzzle boxes, performed one or two actions that are unnecessary for retrieving the reward, then performed one or two actions that are necessary, and finally retrieved the reward. Children were then given the chance to operate on the box, and their responses were coded with regard to the percentage of necessary and unnecessary actions copied for each puzzle box. Inter-rater reliability was high (Cohen's κ = 0.90 for necessary actions, and 1 for unnecessary actions).

2.2.2 | Word learning task

This task examined whether children understand that object labels, but not preferences, are conventional and thus 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. As in the original study, we created two exemplars for 12 object types that were unfamiliar to children. Each object type was associated with one action that causes some effect. The two exemplars were identical in shape and different in color. Each child played with four object types, two for each condition.

In the different-speaker-word condition, E1 first introduced children to two objects that were hidden in two identical boxes: one target object (e.g., "Mido") and one alternative object (not labeled). For each object, E1 opened the box, introduced the object ("This is a Mido!" for the target object and "Look at this!" for the alternative object), demonstrated its associated action, gave children the object to play with, returned the object to the box and closed the box. He then switched the location of the two boxes and introduced the objects again. After that E1 left the room and E2 came in. E2 first conducted the *original* trial, in which she showed children the two original objects and asked for the referent of the novel label (e.g., "Show me the Mido!") Then she conducted the *generalization* trial, in which she repeated the same question for two new objects with the same shape but different color. Finally, she conducted the *dissociation* trial (Diesendruck & Markson, 2001), in which she asked children for the referent of a different novel label (e.g., "Show me the Toma!"). The outcome measurement was a score (out of 3 total points) for reasoning about shared knowledge of object labels: Children received one score each for choosing the target object for the original and generalization trials, and choosing the alternative object for the dissociation trial.

The different-speaker-preference condition was used as a control condition to test whether children assume that preferences are also shared between individuals. This condition is identical to the different-speaker-word condition, except that the labels were replaced by preferences—E1 introduced the target object by saying "I like this one," and E2 asked children "Show me the one I like." The dissociation trial was not administered for this condition, because preference is not mutually exclusive (unlike applying a particular label, one can prefer multiple objects at the same time). The outcome measurement is a score (out of 2) for reasoning about shared preferences: Children received one score each for choosing the target object for the original and generalization trials. The reliability coder agreed with the main coder on all scores.

2.2.3 | Puppet show task

This task evaluated children's imitative behavior after watching a demonstration without an instrumental goal. This task was a shortened version of Carpenter et al. (2005), administered as in the original with the only difference being a reduction of the number of trials from eight to four. Each child completed two trials of house condition and two trials of no house condition in a staggered order. In each trial, children were presented with either a mat with two cardboard houses (house condition) or an empty mat (no house condition). E1 moved a puppet from the edge of the mat to one of the houses (house condition) or to the corresponding location on the empty mat (no house condition). The movement was performed in one of two manners, and each manner corresponded to a particular action style (either hopping or sliding) and a sound effect accompanying the movement (either "beebeebee …" or "beeeeee …"). Children were then given a chance to play with the puppet and the mat, and one coder who was blind to the hypotheses determined whether the child matched E1 on the style of movement, sound effect and final location. Inter-rater reliability was high (Cohen's κ = 0.84, 1, 0.85 for style, sound, and location).

2.2.4 | Artifact function task

This task examined the extent to which children assumed conventionality in tool-use—that artifacts are designed *for* particular purposes. The task we used was a simplified version of the task used in Casler and Kelemen's (2007) study. We duplicated the two novel tools used in the original study, which were physically equivalent but perceptually distinct. We also created three sets of two assignments that were similar to those used in the original study (e.g., ringing a bell in a bellbox and crushing a bag of pasta), and each child was assigned to one set. The two tools were equally affording to the two assignments in each set.

E1 first invited children to insert the two tools into a "holder" with two matching side-by-side slots, and pointed out that both tools fits. This manipulation was to emphasize the tool's physical equivalence. E1 then demonstrated using one of the tools (target tool) to complete one of the assignments (e.g., ringing the bell in the bellbox), and invited children to try themselves. After that E1 displayed the other assignment (e.g., the bag of pasta), put the two tools on either side of the display, blocked this array from children's sight using a screen, completed the assignment (e.g., smashing the pasta) with a tool unbeknown to children, and showed children the end state. Therefore, children had to infer which tool had been used. E1 then asked children which tool they would pick to repeat the first assignment (*original* trial), and which tool they would pick to solve the second assignment (*dissociation* trial). The outcome measurement is a score (out of 2) for normative reasoning about artifact functions: Children received one score each for choosing the target object for the original trial, and choosing the alternative object for the dissociation trial. Inter-rater reliability between the main and reliability coder was 0.90 (Cohen's κ).

2.2.5 | Sorting task

Modified from Yu and Kushnir (2016), this task was administrated to measure children's learning of causal properties of objects, both obvious and non-obvious ones. Stimuli used in the task were cylinder-shaped barrels that vary in both a superficial property (color) and a hidden property (noise made when shaken). Each child completed two trials in increasing difficulty. In the *color-sort* trial, E1 demonstrated sorting four soundless barrels into two boxes according to their color. He then gave children the two boxes and four soundless barrels of two new colors. Children's responses were scored as correct if they sorted these barrels by color. In the *sound-sort* trial, E1 showed children four barrels of the same color, two sound-making and two soundless. He shook each barrel, and sorted them into two boxes based on whether they made a sound. He then gave children the two boxes and four new barrels of the same color, two that can make a different sound and two soundless. Children's responses were scored as correct if they sorted by sound. The final score (out of 2) was used as a measurement of children's causal learning. The reliability coder agreed with the main coder on all scores.

2.2.6 | Theory-of-Mind Scale

This scale (Wellman & Liu, 2004) was used to examine children's understanding about others' mental states. Based on the age of our participants, we used the first three tasks from the scale: the Diverse Desire task, the Diverse Belief task and the Knowledge Access task. The Contents False Belief and the Real-Apparent Emotion tasks were not administered, because children under 36 months of age are unlikely to pass them (Wellman, Cross, & Watson, 2001).[3] For each task, E1 told children a story, in which a protagonist had different desire, belief, or knowledge state than the children themselves. E1 then asked children to predict the protagonist's behavior. Children's answers were considered correct when they inferred that the protagonist's behavior will be consistent with their own, and not the children's, mental state. The tasks were always ordered from the easiest (the Diverse Desire task) to the hardest (the Knowledge Access task), as in the original study. The total number of correct responses (out of 3) was used as a measurement of children's theory-of-mind. The reliability coder agreed with the main coder on all scores.

2.2.7 | Sharing task

This task (Chernyak & Kushnir, 2013) was used to measure children's prosocial behavior. After children completed all other tasks, E1 gave children five stickers as an appreciation for their participation. E1 then presented children with a puppet dog and two boxes. He told children that the doggie is feeling sad, and receiving stickers will make the doggie feel better. However, it was also fine for children to keep their stickers. He then prompted children to distribute the stickers across the doggie's box and their own box. The number of stickers shared with doggie (out of 5) was used as a measurement for children's prosocial behavior. Inter-rater reliability between the main and reliability coder was 0.80 (Cohen's κ).

2.3 | Parental reports

Parents filled out four questionnaires about their children. They either completed these questionnaires during the lab visit, or took them home to finish and mailed back to E1. Parents were told to fill out the questionnaire based on their children's performance at the time of the lab visit.

2.3.1 | Demographic Questionnaire

This questionnaire collected basic information about children and their families. Questions included the children's birth date, gender, race, and ethnicity, whether they were born preterm or full term, history of developmental disorders, number of siblings, length and frequency of day care experience, as well as parents' education level and annual household income.

2.3.2 | CDI

Children's general developmental level was measured through parental reports of the General Development scale from the Child Development Inventory (Ireton, 1992). This scale contained 70 items of milestone achievements, covering domains of social, self-help, gross motor, fine motor, expressive language, language comprehension, letters and numbers. The total number of items parents judged to be present or used to be present in their children was used as a measurement of children's developmental level.

2.3.3 | Macarthur CDI

Children's productive language skills were measured by the MacArthur Communicative Development Inventories (CDI) (Fenson et al., 2000). We used the toddler version (CD–III, Form B), which suited the age range of our participants. The form contained a list of 100 words, and parents were asked to report if children can produce these words. The total number of words children can produce was used as their language skills measurement.

2.3.4 | ECBQ

Children's temperament was measured by the short version of Early Childhood Behavior Questionnaire (Putnam et al., 2006). The questionnaire contained 36 items on three subscales: Surgency/Extraversion, Negative Affectivity, and Effortful Control. Parents rated their children on these items on a 1–7 scale. We used the average subscale scores as measurements for children's temperament.

2.4 | Data analysis

The data presented in this paper will be made available on request. All data were coded and entered into SPSS files. Group-level results were analyzed using IBM SPSS Statistics 22, R 3.2.3, and Excel. PCA

TABLE 2 Descriptive statistics for all measurements used in the study, including parental reports and children's performances in experimental tasks

Task/Questionnaire	Measurement	Range of possible scores	Valid *n*[a]	*M*	*SD*	Range of actual scores
Demographic Questionnaire	Age	—	48	26.0	2.9	23–32
	Number of siblings	—	47	0.94	1.03	0–5
	Daycare/preschool experience[b]	—	48	7.8	11.3	0–39
CDI	Developmental level	0–70	47	38.8	8.3	22–57
McArthur CDI	Language skills	0–100	48	65.5	25.0	14–99
ECBQ	Surgency/extraversion	1–7	48	5.25	0.62	4.05–6.39
	Negative affectivity	1–7	48	2.85	0.64	1.58–4.00
	Effortful control	1–7	48	4.90	0.68	3.42–6.25
Puzzle box task	Copying unnecessary actions	0–3	48	1.30	0.80	0–2.5
	Copying necessary actions	0–3	48	1.85	0.78	0–3
Puppet show task—House condition	Matching style	0–2	46	0.74	0.77	0–2
	Matching sound	0–2	46	0.59	0.78	0–2
	Matching location	0–2	46	1.17	0.77	0–2
Puppet show task—No house condition	Matching style	0–2	45	1.13	0.69	0–2
	Matching sound	0–2	45	0.67	0.80	0–2
	Matching location	0–2	45	0.36	0.57	0–2
Word learning task	Shared object labels	0–3	47	2.06	1.16	0–3
	Shared preferences	0–2	42	0.79	0.78	0–2
Artifact function task	Conventionality of artifact functions	0–2	48	0.96	0.58	0–2
Sorting task	Causal learning	0–2	42	0.43	0.70	0–2
Theory-of-Mind Scale	Theory-of-mind	0–3	37	0.92	0.76	0–2
Sharing task	Prosocial behavior	0–5	41	2.88	2.14	0–5

Abbreviations: CDI, Communicative Development Inventories; ECBQ, Early Childhood Behavior Questionnaire.
[a]Valid *n* denotes the number of children completed each task.
[b]The attendance-adjusted number of months children spent in daycare or preschool (based on an attendance of 30 hr per week).

was implemented with IBM SPSS Statistics 22. CFAs were implemented with the lavaan package of R and AMOS 22.

3 | RESULTS

Table 2 shows the descriptive statistics for all measurements. Among the 48 children, 45 (94%) completed all imitation tasks, and 34 (71%) completed all seven tasks. Fourteen children (29%) failed to provide relevant response to at least one trial in at least one task, and attrition for individual tasks ranged from 0% to 23% (see Table 2). For each analysis reported below, we only excluded children who did not complete all the tasks involved in that analysis. Excluding all children with any missing data for all analyses will not cause qualitative change to any of the findings (see Supporting Information).

Before further analyses, we validated the results in two ways to show that tasks originally used to capture group-level differences in experimental designs can also capture individual differences in a correlational design. First, we compared our group-level results against results of studies from which the tasks were adapted. For the puzzle box task, we replicated previous findings (e.g., McGuigan & Whiten, 2009; Nielsen et al., 2008) in showing a mixture of imitation and emulation at the group level. For the puppet show task, we replicated the result of the original study (Carpenter et al., 2005) in showing different patterns of imitative behavior between conditions: Children matched the manner of the actions more in the no-house condition, and they copied the final locations more in the house condition. We also replicated results of the other tasks at the group level. Detailed statistical analysis for these comparisons is listed in the Supporting Information.

Second, we examined if the tasks were sensitive to the variabilities in our participants (i.e., if there were ceiling or floor effects). For all experimental measurements, the actual score ranges covered at least 80% of the possible score ranges, and the standard deviations of children's performances were higher than ¼ of the possible score ranges. These results indicate that all experimental measurements we used were suitable for children in the target age range, and there were enough variations in each task to support individual differences analyses.

3.1 | Are there consistent individual differences in imitative behavior?

We began by testing whether the mixture of different imitative behavior observed at the group level reflect consistent differences across individual children. To address this, we examined correlations in children's responses both within and across imitation tasks. For the puzzle box task, children's retrieval of reward from each box can be predicted by their reproduction of necessary actions for that box, $rs > 0.42$, $ps < 0.003$, but cannot be predicted by their reproduction of unnecessary actions, $rs < 0.07$, $ps > 0.67$. Their reproduction of necessary and unnecessary actions also correlated across some of the puzzle boxes: For both necessary and unnecessary actions, the correlation between the first set (used in Brugger et al., 2007) and the second set (used in Nielsen et al., 2012) was significant, $rs(46) > 0.4$, $ps < 0.005$. These correlations held after controlling for age, developmental level, and language skills: $rs(42) > 0.4$, $ps < 0.005$. The correlations between the third set (used in Horner & Whiten, 2005; Lyons et al., 2011) and the other two sets was not significant, $ps > 0.09$. This lack of correlation may be due to the fact that the third set is much more causally complex than the first two sets (Table 1).

For the puppet show task, we observed correlations of matching style and sound in both the House condition and No House condition ($rs > 0.44$, $ps < 0.002$), which holds after controlling for age, developmental level, and language skills ($rs > 0.46$, $ps < 0.002$) (Table 3). This shows consistent individual differences in children's faithful imitation of action manners. Moreover, matching style in the No House condition was specifically correlated with matching final location in the House condition (zero-order correlation $r = 0.34$, partial correlation $r = 0.31$, $ps < 0.05$), which suggests individual differences in children's emulation of the demonstrator's intentions which differ by condition (instrumental in the House condition; pedagogical in the No House condition).

When comparing across imitation tasks, the total number of actions children copied in the puzzle box task correlated with the total number of style, sound, and location children matched in the puppet show task, $r(44) = 0.35$, $p = 0.02$, and this result held after controlling for age, developmental level, and language skills, $r(40) = 0.34$,

TABLE 3 Intercorrelations among six outcome measurements in the puppet show task ($n = 45$)

		Style		Sound		Location	
		House	No house	House	No house	House	No house
Style	House	—	0.274	0.446**	0.270	0.153	0.098
	No house	0.276	—	0.310*	0.616***	0.337*	0.222
Sound	House	0.464**	0.297*	—	0.621***	0.197	0.020
	No house	0.271	0.579**	0.638***	—	0.264	0.266
Location	House	0.151	0.307*	0.184	0.207	—	0.147
	No house	0.091	0.181	0.007	0.205	0.074	—

Note: The upper-right triangle shows zero-order correlations; the lower-left triangle shows partial correlations after controlling for age, developmental level, and language skills.
$^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

TABLE 4 Factor loadings based on a principle component analysis for the outcome measurements in the puzzle box task and puppet show task ($n = 45$)

Task	Measurement	Condition	Factors: 1 (faithful imitation)	2 (goal emulation)
Puzzle box task	Copying unnecessary actions		**0.550**	−0.001
	Copying necessary actions		−0.050	**0.808**
Puppet show task	Matching style	House	**0.604**	0.136
		No house	**0.551**	**0.604**
	Matching sound	House	**0.874**	0.031
		No house	**0.792**	**0.413**
	Matching location	House	0.277	**0.598**
		No house	0.063	**0.695**

Bold values indicate factor loadings of at least 0.4.

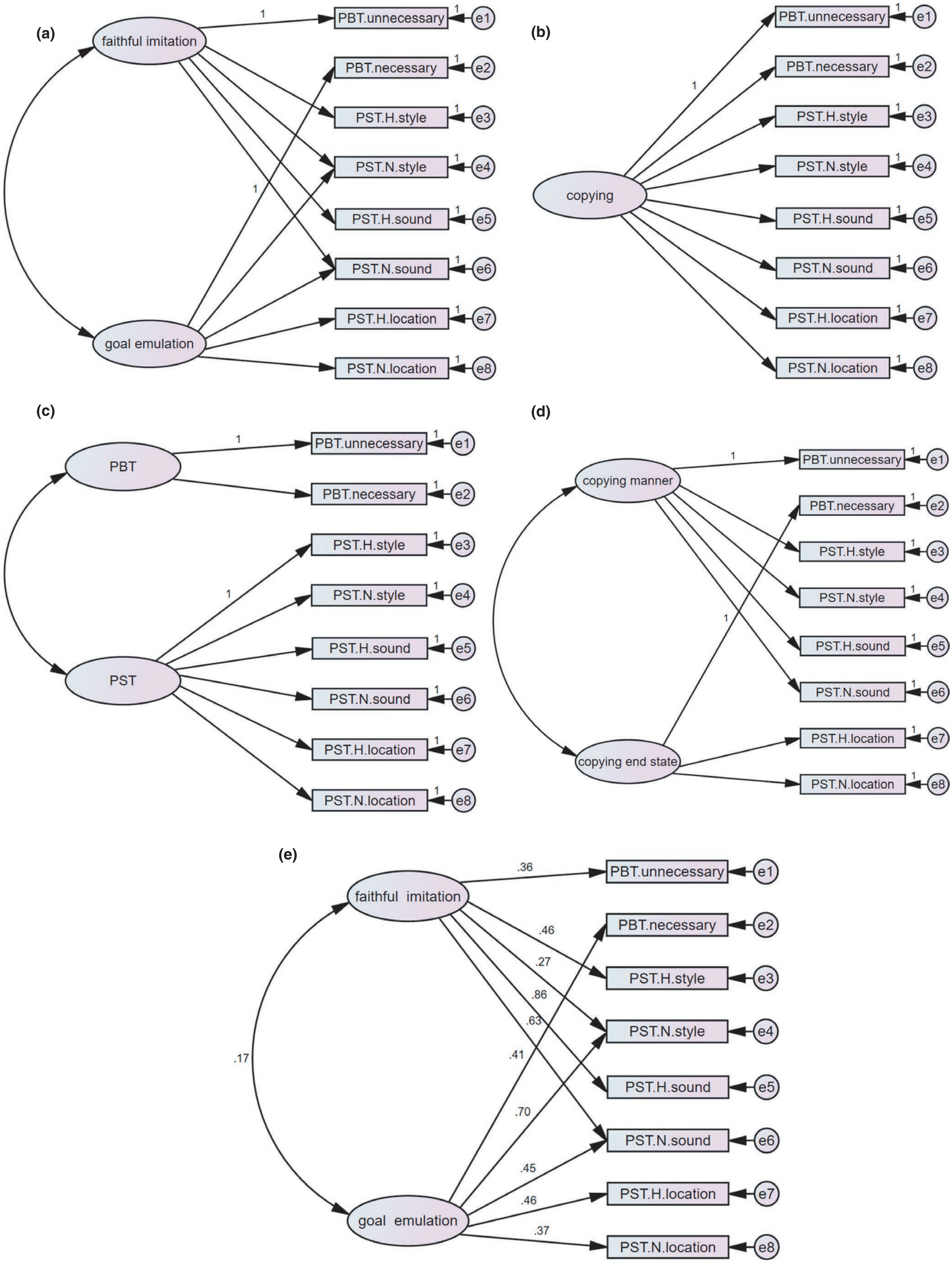
$p = 0.03$. This suggests that individual differences in children's imitative behavior may transcend beyond a particular task.

3.2 | Does imitative behavior vary along how much children imitate faithfully and emulate goals?

Next, we examined the underlying structure of the individual differences observed in children's imitative behavior, and we did so by submitting all outcome measurements from the two imitation tasks to a PCA. Presumption checks showed that our sample size ($n = 45$) was adequate for the analysis (Kaiser-Meyer-Olkin value = 0.63), and the variables were sufficiently correlated (Bartlett's test $p < 0.001$). We used oblique rotation (oblimin) to allow factors to correlate. The covariance matrix for all outcome measurements is listed in Table S2. Results revealed two factors with eigenvalue > 1 (Table 4). The first factor explained 34% of the total variance, and showed high loadings (>0.4) on copying unnecessary actions in the puzzle box task, and matching style and sound in the puppet show task. These measurements reflected a tendency to copy the exact form of the demonstration, therefore we labeled this factor "faithful imitation." The second factor explained 20% of the total variance, and showed high loadings on copying necessary actions in the puzzle box task, matching location in the puppet show task, and matching style and sound in the no house condition of the puppet show task. These measurements reflected a tendency to copy the overarching goal of the demonstrator, therefore we labeled this factor "goal emulation." Two measurements (matching style and sound in the no house condition) showed high loadings on both factors. This was expected, however, because when the demonstrated action lacks an apparent external goal (a house to move the mouse to), infants often infer the particular manner of the action itself to be the goal of the demonstration (Carpenter et al., 2005). Therefore, matching style and sound in the no house condition can reflect either imitating the form of the demonstration, emulating its goal, or both.

To further verify whether individual differences are best explained by factors of faithful imitation and goal emulation, we compared our model derived from PCA (Figure 1a) with three alternative models. The single-factor model (Figure 1b) assumes variations across children to be explained by one generic factor of copying. The task-based model (Figure 1c) assumes variations to be explained by tasks-specific factors. Finally, the manner-end state model (Figure 1d) is identical to the faithful imitation-goal emulation model, except that each measurement from the puppet show task was associated with one factor only (matching style and sound with copying manner, matching location with copying end state) regardless of condition. If children who tend to emulate are indeed focusing on copying the end state of the demonstration (which is the same across house and no house conditions) instead of the demonstrator's overarching goal (which is different across conditions), we should see this model fitting data as well as, or better than, the faithful imitation-goal emulation model.

Model comparison was performed with CFA. For each model, we fitted data from all 48 children, and used full information maximum likelihood to handle missing data.[4] Because our sample is small for running CFAs and the measurements were not normally distributed, we used robust variants of maximum likelihood estimation following Satterthwaite's approach (cf. Muthén, du Toit, & Spisic, 1997).[2] Results showed excellent fit of our faithful imitation-goal emulation model to the data (Table 5), comparative fit index (CFI) = 1.00, Tucker–Lewis index (TLI) = 1.06, root mean square error of approximation (RMSEA) = 0.00. Standardized parameter estimates are shown in Figure 1e. In comparison, the single-factor and task-based models fit poorly to the data, CFIs < 0.84, TLIs < 0.81, RMSEAs > 0.09. The fit for the manner-end state model is also below the commonly-used cutoff criteria for good fit (Hu & Bentler, 1999), CFI = 0.93, TLI = 0.92, RMSEA = 0.063. To estimate the relative of likelihood of different models, we calculated Bayes factors using the Bayesian information criterion (BIC) approximation: $BF = exp(\Delta BIC/2)$ (Wagenmakers, 2007). Results showed that assuming equal priors, the faithful imitation-goal emulation model is 27 times more likely than the manner-end state model, and over 800 times more likely than the single-factor and task-based models. This provides strong support for the faithful imitation-goal emulation model compared to alternative models. We computed composite scores of faithful imitation and goal emulation for each child by taking the sum of their scores on measurements that are linked to each factor.


(a)
faithful imitation
goal emulation
1
1
PBT.unnecessary
PBT.necessary
PST.H.style
PST.N.style
PST.H.sound
PST.N.sound
PST.H.location
PST.N.location
e1
e2
e3
e4
e5
e6
e7
e8
(b)
copying
1
PBT.unnecessary
PBT.necessary
PST.H.style
PST.N.style
PST.H.sound
PST.N.sound
PST.H.location
PST.N.location
e1
e2
e3
e4
e5
e6
e7
e8
(c)
PBT
PST
1
1
PBT.unnecessary
PBT.necessary
PST.H.style
PST.N.style
PST.H.sound
PST.N.sound
PST.H.location
PST.N.location
e1
e2
e3
e4
e5
e6
e7
e8
(d)
copying manner
copying end state
1
1
PBT.unnecessary
PBT.necessary
PST.H.style
PST.N.style
PST.H.sound
PST.N.sound
PST.H.location
PST.N.location
e1
e2
e3
e4
e5
e6
e7
e8
(e)
faithful imitation
goal emulation
.17
.36
.46
.27
.86
.63
.41
.70
.45
.46
.37
PBT.unnecessary
PBT.necessary
PST.H.style
PST.N.style
PST.H.sound
PST.N.sound
PST.H.location
PST.N.location
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e8

TABLE 5 Comparison of model fit between our model, a single-factor model and a task-based model

Model fit statistics	*df*	χ^2	CFI	TLI	BIC	RMSEA	SRMR
Criteria for good fit	–	–	>0.95	>0.95	–	<0.06	<0.08
Imitation-emulation	8.81	7.72	1.00	1.06	360.0	0.000	0.071
Single-factor	8.63	12.46	0.83	0.80	373.5	0.099	0.096
Task-based	8.29	12.14	0.83	0.79	373.6	0.102	0.096
Manner-end state	8.93	10.54	0.93	0.92	366.6	0.063	0.078

Note: We used the robust estimates (Satterthwaite approach) for all statistics. All criteria for a good fit were adopted from Hu and Bentler (1999).
Abbreviations: CFI, comparative fit index; TLI, Tucker–Lewis index; BIC, sample-size adjusted Bayesian information criterion; RMSEA, root mean square error of approximation; SRMR, standardized root mean square residual.

TABLE 6 Correlations coefficients (*r*) between imitative behavior and other measurements

	Zero-order correlation			Partial correlation		
	Faithful imitation	Goal emulation	Total copying	Faithful imitation	Goal emulation	Total copying
Age	0.07	0.31[a]	0.08	–	–	–
Developmental level	0.22	0.46[b]	0.24	–	–	–
Language skills	0.19	0.15	0.11	–	–	–
Number of siblings	−0.10	−0.15	−0.16	−0.25	−0.13	−0.17
Daycare/preschool experience	0.08	0.12	0.08	0.05	0.04	0.06
Surgency/extraversion	0.16	−0.01	0.17	0.15	−0.04	0.16
Negative affectivity	−0.30[a]	0.00	−0.18	−0.31[a]	−0.02	−0.19
Effortful control	0.01	0.02	−0.08	−0.05	−0.16	−0.16
Shared object labels	0.18	0.04	0.07	0.10	−0.13	−0.03
Shared preferences	0.09	0.13	0.00	0.06	−0.03	−0.09
Conventionality of artifact functions	0.22	0.28	0.22	0.18	0.18	0.17
Causal learning	0.10	0.25	0.05	0.06	0.09	−0.01
Theory-of-mind	0.00	0.31	0.18	0.14	0.48[a]	0.32
Working memory	−0.04	0.16	0.15	−0.17	−0.04	0.05
Inhibition	0.16	−0.10	−0.01	0.14	−0.21	−0.04
Prosocial behavior	0.24	0.27	0.12	0.33[a]	0.40[a]	0.20

Note: Partial correlations denote correlations after controlling for age, developmental level, and language skills.
$^*p < 0.05$; $^{**}p < 0.01$.

These composite scores are used to depict how much each child tends to imitate faithfully or to emulate the goal, and the two behavioral routines are not mutually exclusive—children can score high on both or neither. We also computed a total copying score for each child by summing up all imitative measurements.

3.3 | Do variations in imitative behavior relate to other cognitive and social skills?

Table 6 showed the correlations between children's faithful imitation, goal emulation and other aspects of development. The score

FIGURE 1 (a) Model specification for the faithful imitation-goal emulation model. This model assumes "faithful imitation" and "goal emulation" as two latent factors that underlie individual differences in children's imitative behavior. These two factors each associate with specific measurements across different types of tasks and conditions. (b) An alternative single-factor model which assumes one generic factor of "copying" to explain individual differences across all measurements. (c) An alternative task-based model which assumes individual differences to be task-specific. (d) An alternative manner-end state model which assumes measurements to be associated with either copying the manner or copying the end state of the demonstration, regardless of different conditions in the puppet show task. (e) Standardized parameter estimates for the faithful imitation-goal emulation model. Abbreviations: PBT = puzzle box task; PST = puppet show task; H = house condition; *N* = no house condition of faithful imitation was positively correlated with children's age (r = 0.31, p = 0.03) and developmental level (r = 0.46, p = 0.002). After controlling for age, developmental level, and language skills, imitation was positively correlated with prosocial behavior (r = 0.33, p = 0.05), and negatively correlated with the negative affectivity subscale of children's temperament (r = −0.31, p = 0.05); goal emulation was positively correlated with theory-of-mind (r = 0.48, p = 0.01) and prosocial behavior (r = 0.40, p = 0.02). Importantly, the total copying score was not significantly correlated with any of these measurements, which suggest that the correlations were specific to the focus of children's social learning, rather than the overall quantity.

4 | DISCUSSION

We began with three research questions regarding individual differences in children's imitative behavior: whether they are consistent across trials and tasks; whether they are characterized by tendencies to imitate and emulate; and whether they correlate with other aspects of development.

Regarding the first research question, we observed individual differences across trials, stimuli, and conditions within a task. Furthermore, we observed correlations of some of the imitation measurements across tasks that feature different stimuli, context and goal structure, and the correlations cannot be explained by possible confounders like age, developmental level, and language skills. It should be noted though, that the features of the task and the stimuli still influence children's social learning above and beyond these individual differences: For example, while children's tendencies to imitate faithfully or emulate the goal is consistent when facing small puzzle boxes featuring simple causal structures (such as those originally used in Brugger et al., 2007; Nielsen et al., 2012; Yu & Kushnir, 2014), they do not correlate with the same children's imitative behavior when facing larger puzzle boxes with more complex causal structures (such as those originally used in Horner & Whiten, 2005; Lyons et al., 2011). Nevertheless, our results suggest that there are individual differences in imitative behavior that may transcend certain immediate contextual influences.

Our second research question postulates two behavioral routines that underlie the variations observed in children's social learning: One is imitation of the exact means of the demonstrator, regardless of whether the means is relevant to what the demonstrator intends to achieve; the other is emulation of the demonstrator's overarching goal, be it retrieving an award or acting out an action in a particular manner. Results of CFAs showed good fit of this model to our data, and the fit was also significantly better than alternative models that assume other two-factor structures or one generic behavioral routine. These results suggest that individual differences in imitative behavior are best represented by two complementary behavioral components—one in which children imitate faithfully, and one in which they emulate goals (Gleissner et al., 2000).

Our third research question has prompted the examination of specific correlations between faithful imitation, goal emulation, and other aspects of development. As predicted, children's faithful imitation was positively correlated with their sharing behavior after controlling for covariates, which is consistent with the argument that affiliative motivation may underlie faithful imitation (Nielsen, 2006; Over & Carpenter, 2013). Moreover, faithful imitation was negatively correlated with the temperament factor of negative affectivity. This correlation may be due to toddlers high on negative affectivity being less patient or careful when they imitate, but may also be due to toddlers who display more positive emotions being more faithful when they imitate (similar finding see Hilbrink et al., 2013). We did not find correlations between imitation and normative reasoning as predicted. One possible explanation is that compared to preschoolers, toddlers may be less restricted by social norms when they imitate actions—for example, 2-year-olds were much less likely to protest or rectify the "wrong" way of using artifacts than 3-year-olds (Rakoczy, Warneken, & Tomasello, 2008). It would be interesting to test if normative reasoning plays a more important role in imitation for older children.

As predicted, children's goal emulation was positively correlated with theory of mind after controlling for covariates. This is consistent with the argument that social cognition allows flexible copying with regard to the overarching goal of the demonstrator (Carpenter et al., 2002; Gergely et al., 2002; Meltzoff, 1995; Southgate et al., 2009; Williamson & Markman, 2006). In addition, previous research has found that individual infants' attention toward goal-directed actions predicts their theory of mind ability in preschool years, which suggested a continuity in individual differences in social cognition (Brooks & Meltzoff, 2015; Wellman et al., 2008). Our results expand this line of research by showing that toddlers' emulation of goal-directed actions may also fall on this continuity: Toddlers who copy flexibly according to the demonstrators' goals, just like infants who understand intentional actions as goal-directed, are more likely to interpret other's behavior based on their mental states such as desires and beliefs. Children's emulation of goals was also found to correlate with their sharing behavior. This could be explained by a metalizing component in the sharing task: Taking the perspective of the doggie may help children understand the necessity of sharing. The predicted correlation between children's goal emulation and their learning about the causal properties of objects was not significant. One possible explanation is that the causal mechanisms for the puzzle boxes, especially the first two sets, are relatively simple and straightforward. It would be interesting to examine whether individual differences in causal knowledge predict goal emulation in more causally complex imitation tasks.

Taken together, this study provides a first demonstration of how analyzing individual differences can contribute to our understanding of children's social learning and imitation. One major ongoing debate in the research of children's social learning and imitation concerns the mechanisms underlying children's faithful imitation of irrelevant actions, or "overimitation" (Lyons et al., 2007). Different theories has been proposed which attributed this phenomenon to errors in children's causal encoding (Lyons et al., 2011), their social motivation (Nielsen, 2008; Over & Carpenter, 2013), and their normative reasoning (Kenward, 2012; Legare & Nielsen, 2015), among others. Many studies have attempted to differentiate between these theories by experimentally manipulating the task, the model, or the context, and examining the effects on the imitative behavior from randomly-assigned groups of children. Our individual-level results complemented these group-level findings by showing that even when facing a same task in the same context, children of the same age can still vary with regard to their tendencies to faithfully imitate or flexibly emulate. These results imply that individual children may vary in what they focus on during an imitation task—For example, a same task may be interpreted by one child as an opportunity to learn new skills, and by another child as a test of following rules. Therefore, to fully understand children's imitative behavior in a particular scenario, it is necessary to take into account multiple possible motivations individual children may have.

Our results also shed new light on the evolutionary foundations of cumulative culture (Tomasello et al., 1993). Building a cumulative culture requires a balance between transmission and innovation (Legare & Nielsen, 2015; Tennie et al., 2009): Faithful imitation helps maintain cultural knowledge and group cohesion, and flexible emulation supports improvement in efficiency and serves as a basis for innovation. The early emergence of these tendencies may help explain how culturally opaque knowledge can be transmitted and expanded across generations (Užgiris, 1981; Want & Harris, 2002). Our results suggest an intriguing corollary to this well-established result. Perhaps stable behavioral tendencies to imitate and emulate in individual children have group-level consequences. For example, individual differences can serve as a foundation for future division of cognitive labor; some people become "preservers" while others become "innovators."[5] These individual differences may be critical for keeping the transmission-innovation balance required for accumulating and advancing culture.

The sample size of this study is relatively small for an investigation of individual differences, therefore results need to be verified by large scale studies. Also, because we have adopted a fixed order of tasks for all participants, we were not able to directly assess possible effects of fatigue or carry-over, and the main experimenter was not blind to hypotheses of the study. Furthermore, this study features a relatively homogenous sample which is mainly from white families of high socioeconomic status. Given evidence showing cultural variations in children's imitative behavior as well as some of the other measurements included in this study (Berl & Hewlett, 2015; Nielsen, Haun, Kärtner, & Legare, 2017; Slaughter & Perez-Zapata, 2014), future studies need to verify if individual differences in imitation follow a similar structure and have similar predictive powers in other populations. Nonetheless, our findings point out the value of examining individual differences for well-studied imitation tasks, and suggests the necessity of distinguishing faithful imitation and goal emulation as two components underlying children's imitative behavior. It also opens up a new set of questions: For example, if some children at age two are more "imitative" than others, how stable are these differences with age? What is the role of social environment, such as parenting practices, in shaping how children tend to imitate or emulate? Do these differences influence what individual children learn from social interactions? To address these questions, there is a need for future longitudinal research to assess the stability of individual differences in imitative behavior, and to explore its antecedents and consequences. These researches will provide valuable insights into how social learning varies in young children and how such variations support cumulative culture. They may also guide the creation of personalized social environments to support individual children's learning.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author (Dr. Yue Yu, yue.yu@nie.edu.sg) upon reasonable request.

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ENDNOTES

[1] The terms "imitation" and "emulation" have been used to refer to different social learning mechanisms by different group of researchers. Here we adopt the definitions used in Whiten, McGuigan, Marshall-Pescini, and Hopper (2009). Our definition of "imitation" is similar to previous definitions of "blind imitation" (McGregor, Saggerson, Pearce, & Heyes, 2006), "overimitation" (Lyons, Young, & Keil, 2007), and "faithful imitation" (Hilbrink, Sakkalou, Ellis-Davies, Fowler, & Gattis, 2013) in that they all emphasize copying the form of an action or a sequence of actions, although we did not assume the copying to be outcome-insensitive as implied in *blind* or *over*-imitation. Our definition is different from "insightful imitation" (Want & Harris, 2002) or "true imitative learning" (Tomasello et al., 1993) which involves the additional criteria of understanding the goals underlying the action, and is also different from the use of "imitation" as a generic term for social learning. Our definition of "emulation" is similar to previous definitions of "goal-emulation" (Whiten & Ham, 1992) in terms of copying the overarching goal of an action or a sequence of actions, and differs from "object movement re-enactment" (Custance, Whiten, & Fredman, 1999) or "end-state emulation" (Whiten et al., 2009) which focuses on matching the exact physical end states of actions. Our definition also differs from "selective imitation" (Over & Carpenter, 2012), as for emulation the goal could be re-enacted with actions that have not been demonstrated (Carr, Kendal, & Flynn, 2015). We use "imitative behavior" as the generic term for children's responses in an imitation task. It is important to point out that we do not intend for ("insightful imitation") Also, animal literature has distinguished many other low-level social learning mechanisms (Zentall, 2011). We only focus on imitation and emulation as they are the mechanisms most

commonly associated with human children's social learning (Whiten et al., 2009).

[2] The term "overimitation" is coined by Lyons et al. (2007) to describe young children's faithful imitation, which they argue is automatic and inflexible. Though this term is commonly used in the field, we disagree with its implications that children's imitation is automatic or inflexible, and prefer to use the more descriptive term "faithful imitation" instead.

[3] Whether infants and young children under 36 months of age can understand others' false beliefs is a topic of controversy (Dörrenberg, Rakoczy, & Liszkowski, 2018). Regardless, it is well established that children under 36 months of age cannot reliably report their false beliefs through verbal answers to the Contents False Belief or Real-Apparent Emotion tasks, so we did not administer them as part of the Theory-of-Mind Scale.

[4] We thank an anonymous reviewer for informing us about the best practices of running CFAs.

[5] It should be noted that here we are using "innovator" in its broad sense, which is based on the suggestion that innovations can occur on different levels—Carr et al. (2016), for example, has differentiated two types of innovations that are equally important in cumulative culture: "innovation by invention" which results from asocial learning only, and "innovation by modification" which results from a combination of social and asocial learning. Whereas emulation does not necessarily create novel solutions as in "innovation by invention", it does have the potential to modify an existing solution to improve efficiency, as in "innovation by modification." Therefore, emulation has been viewed as a form of innovation (Carr et al., 2016). Moreover, emulation is also considered a precursor to "innovation by invention" in childhood (Whiten & Flynn, 2010), because it shows cognitive flexibility and causal understanding that are crucial to discovering new solutions to a problem.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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