A LONGITUDINAL EXAMINATION OF IMITATION RECOGNITION IN CHILDREN WITH AUTISM SPECTRUM DISORDER

By

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Psychology – Master of Arts

2021

ABSTRACT

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Children with autism spectrum disorder (ASD) have significant difficulties engaging in imitative behaviors, which can have cascading developmental effects on subsequent social communication skills. Although there is a substantial body of research on imitation in children, research on imitation recognition is extremely limited, despite its theoretical significance. The current study examined the longitudinal trajectory of imitation recognition during a period of contingent imitation by an adult in a sample of 51 children with ASD over a 9-month period. Results indicated that rates of implicit and explicit imitation recognition as well as the proportion of explicit imitation increased over time, consistent with their developmental emergence in children without ASD. Multilevel modeling indicated a main effect of implicit imitation recognition on receptive language and expressive vocabulary, suggesting the relationship between these skills in children with ASD. In addition, there was a marginally significant time by explicit imitation recognition interaction in predicting receptive language, indicating that children who demonstrated higher rates of explicit imitation recognition at baseline made greater gains in receptive language over time than those with lower rates of explicit imitation recognition. The clinical implications of these results suggest that early interventions that target imitation recognition may support the development of language skills in children with ASD.

ACKNOWLEDGEMENTS

I could not have completed this work without the constant encouragement, support, and guidance from my mentor, Brooke Ingersoll. I would also like to thank my committee members, Amy Drahota and Emily Durbin, and lab mates, Kyle Frost and Diondra Straiton, for their mentorship throughout this process. I am incredibly grateful for my family's unconditional support and love, especially my parents Ana Ramos Soto and Miguel Pomales Castro. I also want to thank Theo Schwarz, Emily Lam, Myla Ona, Mari Guerra, and Esther Chen for their constant enthusiasm, support, and videocalls.

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INTRODUCTION

Imitation serves as a tool for social exchange across the lifespan (Contaldo et al., 2016). During early development, infants use imitation as their main form of communication and knowledge acquisition (Nadel, 2002; Vivanti et al., 2014). As children's social and cognitive skills develop, their imitative abilities become more sophisticated and occur more frequently (Vivanti et al., 2014). Through engaging in imitative behaviors, children learn novel skills (i.e. turn taking, role reversal, sharing information, gain new play skills) that facilitate social orientation and understanding, language development, and reciprocal communication with their peers (Carpenter et al., 2013; Nadel et al., 2004; Toth et al., 2006). Therefore, imitation is a foundational skill that supports the development of cognition, reciprocity, and social learning.

Children with autism spectrum disorder (ASD) have significant difficulties engaging in imitative behaviors (Nadel, 2002; Rogers et al., 2003; Rogers & Pennington, 1991.; Vivanti et al., 2014; Williams et al., 2004), including imitating actions, facial expressions, gestures, and actions with objects (Colombi et al., 2009). Studies have found that children with ASD imitate less frequently and accurately than their typically developing peers (Colombi et al., 2009; Toth et al., 2006).

Deficits in imitation skills can have cascading developmental effects on subsequent social and cognitive skills. Previous research has demonstrated that imitationskills are predictive of language, joint attention skills, communication abilities, and theoryof mind (Rogers, 1999; Rogers & Pennington, 1991). These findings support the role thatearly imitative behaviors play in the development of more advanced social-communication skills. Delineating the developmental trajectory of imitative behaviors is crucial to further our understanding on how this early developmental process unfolds.

Meltzoff's "like-me" framework suggests that an individual's ability to imitate is related to their ability to perceive that another person's behaviors are parallel to their own (i.e., recognizing others can act "like-me"). Therefore, there are two core mechanismsthat underlie all imitative behaviors: the ability to recognize imitation (i.e., imitation recognition) and the ability to imitate an observed behavior (i.e., imitation production; Meltzoff, 2007). Interestingly, neural studies have supported this theory by identifying common brain regions in the mirror neuron system that activate during both imitation recognition and imitation tasks (Sasaki et al., 2018). Therefore, the same mechanisms used to observe and recognize imitation are used to perform imitation.

Meltzoff (2007) hypothesized that the ability to recognize imitation emerges during early infancy. Infants learn to map the relationship between their own mental states and their actions through observing others behaving like them (Meltzoff, 2007). Meltzoff (2007) explained that social exchanges during which an infant is being imitated provide the child with the opportunity to recognize parallel behaviors and understand the intentions of their imitative partner. Therefore, recognizing that others can be "like-me," enables the development of social and cognitive skills.

This framework has been utilized to understand the social impairments in ASD and other developmental delays (Meltzoff, 2010; Meltzoff & Decety, 2003; Rogers & Pennington, 1991). Observational studies have shown that individuals with ASD may have deficits (e.g., gaze following, emotion understanding) that disrupt the "like-me" mechanism, subsequently impairing the development of social and cognitive skills (Meltzoff, 2007). This suggests that challenges with imitation production may play a central role in social and communicative skills difficulties in children with ASD.

While children with ASD can demonstrate significant difficulties with imitation production, studies have found that they are able to recognize when they are being imitated (Berger & Ingersoll, 2013, 2015; Nadel et al., 2004). In fact, following a period ofcontingent imitation (i.e., when someone imitates the exact action at the same time the child is performing the action), children with ASD were more likely to engage in higher frequency of social behaviors such as looking toward the examiner and referencing the examiner's toy (Field et al., 2013; Heimann et al., 2006; Nadel et al., 1999; Sanefuji & Ohgami, 2011, 2013).

Field and colleagues (2013) utilized an adapted Still Face paradigm (Nadel, 2002) to examine the unique responses of being imitated when compared to other social exchanges in children with ASD between the ages of 4 to 6 years. The adapted Still Face paradigm included four, 3-minute phases: first still face interval (i.e., an unfamiliar examiner remained expressionless and did not interact with the child), interaction phase, second still face interval, and free play. During the interaction phase, participants were randomly assigned to the perfect imitation or responsive interaction group. Findings revealed that children with ASD in the imitation condition demonstrated increased social attention to the examiner (i.e., referential looking, gaze following, eye contact) during and after the imitation phase when compared to children in the responsive interaction condition. These findings suggest that children with ASD are able to readily discriminate being imitated from other social responses, as well as show increased social attention in response to being imitated.

Similarly, Sanefuji and Ohgami (2011) utilized the Still Face paradigm to compare how typically developing children and children with ASD respond to either the perfect imitation or responsive interaction condition. They had a parent complete the still face paradigm, as opposed to an unfamiliar examiner (Fields et al., 2013). Sanefuji and Ohgami found that children with ASD who participated in the imitation condition displayed significantly more social attention when compared to those participating in the responsive interaction condition. However, they demonstrated significantly less social attention than their typically developing peers. Taken together, these findings suggest that children with ASD can discriminate imitative actions from other social exchanges performed by both familiar and unfamiliar adults, despite demonstrating less frequent social attention.

While increased social attention towards imitative behaviors may indicate an awareness of being imitated, it does not explicitly demonstrate an understanding of the communicative intentions of the individual imitating the behavior (Nadel, 2002). In a series of observational studies, Nadel and colleagues identified two levels of imitation recognition behaviors that follow a developmental sequence: implicit or lower-level imitation recognition behaviors and explicit or higher-level imitation recognition behaviors (Field et al., 2001; Nadel, 2002; Nadel et al., 2004).

Lower-level behaviors include directing social attention towards the imitative partner (i.e., looking at the imitative partner or referencing their toy) and indicate a general awareness of being imitated (Nadel, 2002). Higher-level imitation recognition behaviors include testing the imitative partner's communicative intentions. For example, Meltzoff (1995) described that child may perform a sudden or unexpected action to test whether their imitative partner explicitly intended to imitate them (i.e., testing behaviors).

These higher-level imitation recognition behaviors indicate an explicit understanding that the person imitating them intended to do so (Nadel, 2002, 2004). Additionally, lower- and higher-level imitation recognition develop in sequence. Nadel (2002) described that first children develop an awareness that others can imitate their actions (lower-level imitationrecognition) and then they gain an explicit understanding of the communicative intentions of the person imitating them (higher-level imitation recognition).

Research on imitation recognition skills have largely focused on examining lower-level imitation recognition behaviors. Nadel (2002) was one of the first to examine both lower and higher-level imitation recognition behaviors cross-sectionally within a sample of 27 pre-school aged children with ASD. They observed possible imitation recognition behaviors including: no reaction, looks at experimenter, looks at experimenter plus social signal, alternates look between the experimenter's object and their own, test experimenter's intentions. They found that while all children with ASD engaged in behaviors related to orienting their attention to the experimenter, only 5 engaged in behaviors testing the experimenter's intentions.

More recently, Berger and Ingersoll (2013) built on the initial findings of Nadel (2002) by examining the extent to which 30 children with ASD between 22-93 months engage in lower-level (i.e., less mature; LM) and higher-level (i.e., more mature; MM) imitation recognition behaviors, as well as the relationship between imitation recognition behaviors and social cognitive skills. A factor analysis confirmed that LM and MM imitation recognition behaviors cluster together meaningfully, as suggested by Nadel (2002). Similar to Nadel (2002), they found that while all children engaged in less-mature imitation recognition behaviors, only 63.3% of children engaged in more-mature imitation recognition behaviors. Taken together, these cross-sectional examinations of imitation recognition suggest sequential development of LM and MM imitation recognition behaviors, as MM imitation recognition behaviors only occur if a child also engages in LM imitation recognition.

Additionally, Berger and Ingersoll (2013) found that MM imitation recognition behaviors were associated with more advanced social-cognitive behaviors, including language and imitation. In a follow up study, Berger and Ingersoll (2015) replicated and expanded on their previous work by comparing LM and MM imitation recognition in children with and without ASD. They found that children with ASD engaged in less frequent imitation recognition behaviors when compared to their typically developing peers. While imitation recognition was closely associated with social-cognitive skills in children with ASD, there was no significant association between these skills and imitation recognition in typically developing children. Therefore, imitation recognition may play a unique role later in development for children ASD. Additional information is needed to understand how imitation recognition skills develop over time in children with ASD and their effect on other social-cognitive skills.

Although there is a substantial body of research on imitation in children, research on imitation recognition is extremely limited, despite its theoretical significance. Further, while a number of studies have examined the development of imitation skills over time, previous research on imitation recognition has been exclusively cross-sectional and used small samples. Thus, there is limited understanding of the developmental trajectory of imitation recognition in relation to imitation, as well as other key developmental processes, such as language and joint attention.

The longitudinal examination of imitation recognition can yield important information about developmental sequelae in young children with ASD (i.e. whether imitation recognition are related to language acquisition and social development) and how deficits in social communication skills unfold. In addition, identifying these key early developmental processes can potentially inform and refine interventions for children with

ASD in order to more effectively address social communication development.

The current study expanded on previous research by Berger and Ingersoll (2013; 2015) by examining the longitudinal trajectory of imitation recognition during a period of contingent imitation in a new and a larger sample of children with ASD over a 9-month period. In line with previous literature, we measured both less mature (i.e., LM) and more mature (i.e., MM) imitation recognition behaviors during periods of contingent imitation by an adult (Berger & Ingersoll, 2013, 2015).

This longitudinal examination allowed us to delineate the developmental trajectory of imitation recognition more broadly, as well as less mature and more mature imitation recognition specifically. We expected to see an increase in the percentage of both LM and MM imitation recognition behaviors over time. Additionally, we expected to see an increase in the proportion of MM behaviors over time.

METHODS

Participants

A total of 53 children between the ages of 18.2 and 93.3 months were included in the current study. All participants were enrolled in an ongoing randomized control trial (RCT) of a telehealth-delivered parent-mediated intervention targeting social communication skills (Ingersoll, 2010). To enroll in the parent study, participants had to be between the ages of 18 and 96 months, have a community diagnosis of ASD based on DSM-5 criteria (APA, 2013), meet criteria for ASD on the Autism Diagnostic Observation Schedule (ADOS-2; Lord et al., 2000), and have an expressive language age of less than 48 months measured by the Mullen Scales of Early Learning (MSEL; Mullen, 1995). Out of the total participants enrolled in the RCT (*N* = 77), only 53 participants had completed both the baseline and 9-month follow up visits at the time of the current study. Furthermore, two participants were excluded due to poor video quality on the imitation recognition assessment, resulting in a final sample size of 51 children. See Table 1 for participant demographics.

Table 1.
Demographic information.

	N	**%**
Gender		
Female	12	23.53
Male	39	76.47
Race		
White	38	74.5
Black or African American	4	7.84
Asian	4	7.84
More than one race	8	15.69
American Indian/Alaska Native	1	1.96

Measures and Design

Participants were administered standardized measures of developmental functioning, receptive and expressive language ability, expressive vocabulary, functional communication skills, response to joint attention (RJA), and imitation. Imitation recognition was measured from video of the 5-minute contingent imitation portion of the imitation assessment. All study measures were administered at study entry and 9 months later (i.e., follow up). Communication and expressive vocabulary standardized measureswere also administered 3-4 months after study entry.

Communication Skills

The Mullen Scales of Early Learning is a standardized assessment that is used to measure cognitive abilities and motor development in children. All assessments were completed at the MSU Autism Lab by an examiner and with the child's caregiver present. For the purpose of this study, we examined the receptive language (scores range 0-48) and expressive language subdomains (score range 0- 50). The assessment was administered at baseline and 9-month follow up.

The MacArthur-Bates Communicative Development Inventory (MCDI; Fenson et al., 2006) is a parent-reported checklist designed to measure vocabulary comprehension and production in infants and toddlers. The sum total number of words reported under "understands and says" (words and gestures form) and words produced (words and sentences form) was used as a measure of expressive vocabulary. Parents completedthe checklist at baseline, after 3-4 months, and after 9 months. Previous research indicates the test-retest reliability of the MCDI is 0.95 (Fenson et al., 1994).

The Vineland Adaptive Behavior Scales, 2nd edition (VABS; Sparrow et al., 2005)is a structured parent interview designed to assess adaptive functioning across various domains, including: communication, daily living, socialization, and motor skills. For the purpose of this study, we only examined the communication domain. An average of the expressive and receptive language domain raw scores was used as a measure of functional communication skills. Parents were interviewed at baseline, after 3-4- months, and 9-month following the initial baseline visit.

Joint Attention

The *Early Social Communication Scales* (ESCS; Mundy et al., 2003) is an observational measure of social interaction and communication used to examine young children's response to joint attention. In order to measurethe child's ability to respond to joint attention, the examiner directed the child's attention to 8-distal and 6-proximal targets by calling their name and pointing their index finger while simultaneously looking at the targets. Responding to joint attention scores consistedof the percentage of correct looks to the target (range 0 - 100). Participants were administered this assessment at baseline and 9-month follow-up visit.

Imitation

The Unstructured Imitation Assessment (UIA; Ingersoll & Meyer, 2011)was used to examine spontaneous object imitation in an unstructured social-interactive context. To complete the UIA, the examiner and child were seated on the floor and provided with two sets of identical toys. The child was presented with 10 object imitationtasks consisting of a target action paired with a verbal marker. For each task, the examiner would first say "watch me" and then model the action three times. The examinerdid not provide specific instructions to imitate the action in order to allow for spontaneousimitation.

Prior to the first trial, the experimenter imitated the child's play with the duplicate toy (i.e., contingent imitation) for approximately five minutes. Additional periods of contingent imitation were interspersed between trials and lasted for about 45 seconds. Spontaneous imitation was measured during each trial and scored as 0 = no imitation, 1 = partial imitation, 2 = complete imitation (total scores ranged from 0 to 18). Participants were administered this assessment at baseline and 9-month follow-up visit. The UIA demonstrated good to excellent internal consistency (Cronbach's alpha = 0.78). Reliability was calculated by two independent observers for 25% of study participants (Kappa = 0.98).

Imitation Recognition

Video of the UIA contingent imitation period was utilized to code imitation recognition behaviors. Trained coders scored children's imitation recognition behaviors during the initial 5-minute period of contingent imitation prior to thefirst imitation task. Length of the contingent imitation period ranged from 4.16 to 5.10 minutes. During this period, examiners imitated the child's movements, vocalizations, andplay (utilizing the duplicate toys). Imitation recognition behaviors were scored using occurrence/nonoccurrence data in 10-second intervals.

Behavioral definitions for imitation recognition behaviors were developed based on Meltzoff's (1995) and Nadel's (2002) descriptions of imitative development and previous examinations of imitation recognition in children with ASD (Berger & Ingersoll, 2013; 2015). Imitation recognition behaviors included: looking at the examiner's toy or face, looking at the examiner while social signaling (i.e., laughing, reaching, offering), alternating looks between their own toy and the examiner's toy, testing behaviors (i.e., child performs a sudden or unexpected action in order to test whether the experimenter intends to imitate them), and verbal signaling (i.e., child verbally acknowledges that theyknow they are being imitated). See Table 2 for operational definitions.

Table 2.
Operational Definitions of Imitation Recognition Behaviors (Berger & Ingersoll, 2013; Nadel, 2002; Meltzoff, 2007)

Imitation Recognition Behavior	**Description**
Look at the experimenter's toy	Child looks at the experimenter's toy during contingent imitation interaction.
Look at the experimenter's face	Child looks at the experimenter's face during contingent imitation interaction.
Look at the experimenter and social signal	Child directs their attention to the experimenter while simultaneously engaging in a social signal (e.g., laughs, smiles, points, reaches) during a period of contingent imitation.

Raters were trained to 80% reliability to master codes. Reliability was established by two independent raters for 16% of the videos. Overall percentage agreement was usedto establish interobserver reliability across the six behaviors (Table 3). Verbal signaling was excluded from the analysis, as preliminary descriptive statistics revealed no children engaged in this imitation recognition behavior. Occurrence and nonoccurrence percent agreement were calculated to account for low-occurrence behaviors and variation in the frequency of imitation recognition behaviors between participants.

Table 3.
Reliability

	Overall PercentageAgreement
Less Mature Imitation Recognition	92.27%
Looks Face	95.89%
Looks Toy	88.66%
More Mature	96.27%
Looks and Social Signal	95.37%
Alternates	95.85%
Testing Behaviors	97.58%

Data Analysis

Based on previous theory, Imitation recognition behaviors were collapsed into two categories representing less mature (i.e., LM) and more mature (i.e., MM) imitation recognition (Berger & Ingersoll, 2013, 2015; Nadel, 2002). To derive an estimate of how often the children engaged in any imitation recognition as well as LM and MM, the numberof intervals in which the relevant behavior occurred was divided by all possible intervals.To understand the relative proportion of time the children spent in MM imitation recognition, the number of intervals in which MM was observed was divided by the total number of intervals in which any imitation recognition behavior (LM + MM) was observed.In order to determine if the rate of imitation recognition behaviors, as well as the proportionof MM significantly changed over 9-months, paired samples t-tests were conducted between relevant scores at baseline and follow up.

Multilevel growth models (MLM) were used to examine the effects of imitation recognition on each social cognitive skill, including imitation, communication, expressive vocabulary, and RJA skills. This is the first examination of imitation recognition as a predictor for social communication skills; therefore, a multilevel analysis was conducted in which each social cognitive skill was predicted to be a function of fixed effects for baseline imitation recognition (either LM or MM), time, and their interaction. The first multilevel growth model (i.e., Model 1), examined the effects of LL imitation recognition behaviors and the interaction between LM imitation recognition*time on each social- cognitive skill. The second multilevel growth model (i.e., Model 2), examined the effects of MM imitation recognition behaviors and the interaction between MM imitation recognition*time on each social-cognitive skill. LM and MM imitation recognition scores at baseline were grand mean centered prior to analysis. Significant interactions were further analyzed using simple slope models to explain the association between imitation recognition and social-cognitive skills.

RESULTS

Imitation Recognition Development

Rate of Imitation Recognition Behaviors

When examining the rate of imitation recognition behaviors across all intervals, descriptive statistics revealed that at baseline, children were engaging in high rates of LM imitation recognition behaviors (M = 24.45, SD = 12.82) and low rates of MM imitation recognition behaviors (M = 12.31, SD = 15.07). At follow up, children increased the rateof LM imitation recognition behaviors (M = 33.10, SD = 16.99) and MM recognition behaviors (M = 21.08, SD = 17.25; table 4).

Furthermore, all children engaged in LM imitation recognition behaviors at baseline and follow up. However, only 75.4% of children engaged in MM behaviors at baseline and 89.36% at follow up. Of the total children who did not engage in any MM imitation recognition behaviors at baseline, 61.5% were able to engage in MM behaviors at follow up.

Table 4.
Paired samples t-test examining percentage of imitation recognition behaviors

	Baseline M(SD)	Follow Up M(SD)	t	df	p
LM imitation recognition	24.64(13.03)	33.10(16.99)	-3.052	46	.004
MM imitation recognition	12.27(15.44)	21.08(17.26)	-4.402	46	<.001

Change in Imitation Recognition Over Time

Paired samples t-tests revealed there was a significant increase in LM imitation recognition behaviors from baseline to follow up (t (46) = -3.052, p = .004). Furthermore, there was a significant increase in MM imitation recognition behaviors from baseline to follow up (t (46) = -4.402, p <.001; table 4). Therefore, children showed a significant increase in both LM and MM imitation recognition behaviors over a period of 9 months. In terms of the proportion of LM and MM imitation recognition, the proportion of intervalsthe children engaged in MM behaviors increased from baseline (M = 27.92, SD = 26.24) to follow up (M = 37.92, SD = 23.14; t (46) = -2.371, p <0.002; Table 5), suggesting that children were more likely to use MM behaviors over time.

Table 5.
Paired samples t-test examining proportion of imitation recognition behaviors

	Baseline M(SD)	Follow Up M(SD)	t	df	p
LM imitation recognition	72.08(26.24)	62.51(23.14)	2.371	46	.022
MM imitation recognition	27.92(26.24)	37.49(23.14)	-2.371	46	.022

Association between Imitation Recognition and other Social Communication Skills

Preliminary Analysis for Multilevel Models

Paired samples t-tests were used to examine whether there was a significant change in children's imitation, receptive and expressive language ability, expressive vocabulary, functional communication, and response to joint attention skills over 9- months (Table 6). Results indicated there was not a significant change in joint attention and imitation production skills during the study period, therefore imitation and joint attention skills were removed from subsequent analyses.

Table 6.
Paired samples t-test examining social cognitive skills

	Baseline M(SD)	Follow Up M(SD)	t	df	p
Imitation	7.33(5.12)	7.78(4.75)	-.608	50	.546
Response to Joint Attention	58.23(24.01)	62.85(25.43)	-1.51	48	.137
Receptive Language	19.86(8.44)	23.98(9.32)	-5.38	48	<.001
Expressive Language	19.35(8.64)	23.55(10.12)	-5.27	48	<.001
Expressive Vocabulary	189.94(220.85)	299.70(256.24)	-5.40	46	<.001
Functional Communication	73.63(13.79)	79.15(16.64)	-4.55	47	<.001

Multilevel Models

Multilevel models using restricted maximum likelihood estimation were used to examine whether language skills were predicted to be a function of fixed effects for baseline imitation recognition (i.e., LM or MM), time, and their interaction (i.e., baseline Imitation Recognition*Time). The models were controlled for participants' chronological age. Imitation recognition scores were grand-mean centered and time and chronological age were coded in months.

Receptive Language*.* The first model examined the effects of LM imitation recognition on receptive language skills as measured by the MSEL. Fixed effects of LM imitation recognition, time, and chronological age were statistically significant. Therefore, children who engaged in higher rates of LM imitation recognition and who were older scored higher on receptive language tasks on average. Furthermore, on average, children demonstrated improvement in receptive language over time. Additionally, children who engaged in higher rates of LM imitation recognition at baseline had higher receptive language skills over time. However, the LM*time interaction was not statistically significant, indicating that receptive language growth over time was not dependent on children's ability to engage in LM imitation recognition skills at baseline (Table 7).

Table 7.
Multilevel Models with receptive language as a function of imitation recognition (IR)

Parameter	Estimate	SE	df	t	p
Model 1: LM IR					
Intercept	20.902	1.120	47.779	18.832	<.001
LM IR	.195	.087	47.780	2.231	.030
Age	.286	.061	47.678	4.659	<.001
Time	.504	.093	46.678	5.384	<.001
LM IR*Time	-.006	.007	46.586	-.856	.396
Model 2: MM IR					
Intercept	20.909	1.172	47.767	17.837	<.001
LM IR	-.014	.078	47.760	-.180	.858
Age	.287	.064	47.815	4.455	<.001

Table 7. (cont'd)

Time	.501	.090	45.726	5.564	<.001
MM IR*Time	.012	.006	36.530	1.980	.055

The second model examined the effects of MM imitation recognition on receptive language skills. The interaction between MM imitation recognition skills and time was marginally significant, as well as the fixed effects of time and chronological age. Therefore, older children had higher receptive language scores. On average, children demonstrated an improvement in receptive language skills over time. Lastly, children whoengaged in higher rates of MM imitation recognition behaviors at baseline showed greaterimprovement in receptive language skills over time. Simple slopes analyses were conducted to further examine this interaction. Children who engaged in higher rates of MM imitation recognition demonstrated accelerated growth in their receptive language skills compared to children who engaged in less frequent MM imitation recognition behaviors (Table 7; Figure 1).

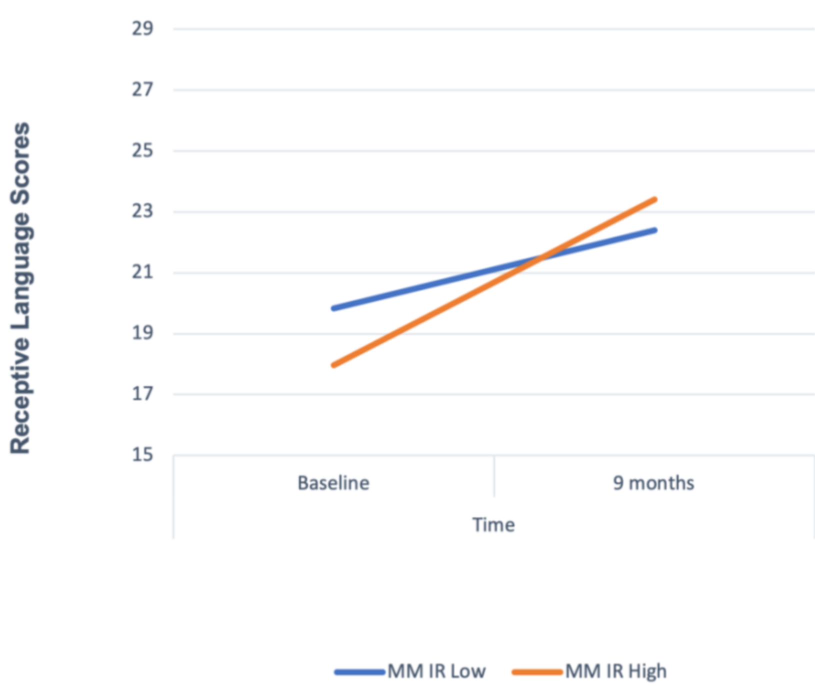

Figure 1.
Simple Slope for the effect of MM IR on Receptive Language Growth

Expressive Language. The first model examined the effects of LM imitation recognition on expressive language skills as measured by the MSEL. The fixed effect of chronological age and time were significant. On average, older children had higher expressive language scores and children improved their expressive language scores over time. However, there was neither a significant LM imitation recognition main effect nor significant LM*time interaction (Table 8). Therefore, LM imitation recognition was not related to expressive language and did not uniquely predict expressive language growth.

The second model examined the effects of MM imitation recognition on expressive language skills. The fixed effect of time and chronological age were significant. On average, older children had higher expressive language scores, and children improved their expressive language scores over time. However, there was neither a significant MM imitation recognition main effect nor significant MM*time interaction (Table 8). Therefore, MM imitation recognition was not related to expressive language and did not uniquely predict expressive language growth.

Table 8.
Multilevel Models with expressive language as a function of imitation recognition (IR)

Parameter	Estimate	SE	df	t	p
Model 1: LM IR					
Intercept	20.403	1.127	48.291	15.955	<.001
LM IR	.139	.101	48.303	1.380	.174
Age	.245	.694	47.431	3.537	<.001
Time	.507	.096	44.676	5.277	<.001
LM IR*Time	.006	.008	41.305	.817	.418
Model 2: MM IR					
Intercept	20.399	1.30	48.19	15.675	<.001
LM IR	.028	.087	48.184	.326	.746
Age	.249	.070	47.464	3.522	<.001
Time	.507	.097	44.856	5.225	<.001
MM IR*Time	.001	.006	36.628	.141	.888

Expressive Vocabulary. The first model examined the effects of LM imitation recognition on expressive vocabulary on the MCDI. Fixed effects of LM imitation recognition, time, and chronological age were statistically significant. Therefore, on average, children who engaged in higher rates of LM imitation recognition scored higher on expressive vocabulary on the MCDI. Older children had higher expressive vocabulary scores. Additionally, children improved their expressive vocabulary scores over time. However, the interaction of LM imitation recognition and time was not statistically significant; thus, expressive vocabulary growth over time was not dependent on children's ability to engage in LM imitation recognition skills at baseline (Table 9).

The second model examined the effects of MM imitation recognition on expressive vocabulary. Fixed effects of time and chronological age were statistically significant. On average, children who were older at baseline had a larger expressive vocabulary and children demonstrated improvement in expressive vocabulary over time. However, the main effect of MM imitation recognition, as well as the MM*Time interaction were not statistically significant, suggesting that the ability to engage in MM imitation recognition was not related to expressive vocabulary and MM imitation recognition skills at baseline did not predict changes in expressive vocabulary (Table 9).

Table 9.
Multilevel Models with expressive vocabulary as a function of imitation recognition (IR)

Parameter	Estimate	SE	df	t	p
Model 1: LM IR					
Intercept	189.761	28.89	48.504	6.567	<.001*
LM IR	4.618	2.270	48.408	2.034	.047*
Age	4.187	1.570	46.853	2.667	.010*
Time	13.750	2.450	47.558	5.610	<.001*
LM IR*Time	.024	.191	45.019	.127	.899
Model 2: MM IR					
Intercept	190.69	30.159	48.410	6.323	<.001
LM IR	.271	2.013	48.257	.135	.893
Age	4.332	1.639	46.880	2.642	.011

Table 9. (cont'd)

Time	13.75	2.447	47.338	5.60	<.001
MM IR*Time	.041	.157	42.167	.259	.797

Functional Communication Skills*.* The first model examined the effects of LM imitation recognition on parent-reported functional communication skills. The fixed effectof time was significant, meaning children improved their communication skills over time. However, there was no significant LM imitation recognition main effect, chronological age fixed effect, or LM*time interaction (Table 10). Therefore, LM imitation recognition did not uniquely predict communication skills or communication skill growth.

The second model examined the effects of MM imitation recognition on parent reported functional communication skills. The fixed effect of time was significant, meaning children improved their communication skills over time. However, there was no significant MM imitation recognition main effect, chronological age fixed effect, or LM*time interaction (Table 10). Therefore, MM imitation recognition did not uniquely predict functional communication skills or communication skills growth.

Table 10.
Multilevel Models with communication skills as a function of imitation recognition (IR)

Parameter	Estimate	SE	df	t	p
Model 1: LM IR					
Intercept	74.395	1.977	50.024	37.625	<.001
LM IR	.171	.156	49.927	1.102	.276
Age	-.120	.108	47.766	-1.118	.269
Time	.703	.154	48.694	4.560	<.001
LM IR*Time	.001	.012	45.815	.066	.948
Model 2: MM IR					
Intercept	74.411	1.99	50.115	37.390	<.001
LM IR	.092	.133	49.830	.688	.495
Age	-.120	.108	47.694	-1.115	.270
Time	.696	.149	48.561	4.658	<.001
MM IR*Time	.016	.009	41.594	1.675	.101

DISCUSSION

The first purpose of this study was to explore the developmental trajectories of a variety of imitation recognition behaviors. Previous descriptive research has suggested that imitation recognition follows a developmental sequence, with less mature imitation recognition behaviors developing prior to more mature imitation recognition behaviors (Nadel, 2004). While previous research examined longitudinal changes in less mature imitation recognition behaviors (Sanefuji & Ohgami, 2013), no study to date has explored how more mature imitation recognition behaviors change over time. This is the first empirical study to examine the longitudinal development of both levels of imitation recognition behaviors.

Consistent with previous findings by Sanefuji and Ohgami (2013), the current study found that the rate of less mature imitation recognition behaviors significantly increased over time. Findings also revealed that more mature imitation recognition behaviors significantly increased over a period of 9-months. Thus, children engaged in higher ratesof less and more mature imitation recognition behaviors over time.

A closer examination of the proportion of intervals engaged in LM and MM imitation recognition behaviors revealed that while children engaged in more LM than MM imitation recognition behaviors at both timepoints, children increased their proportion of engagement in MM imitation recognition behaviors over time. Taken together, these findings support the assertion that LM and MM imitation recognition develop in sequence, with LM imitation recognition preceding the development of MM imitation recognition. Gaining awareness of being imitated (i.e., LM imitation recognition) supports the development of understanding communicative intentions (i.e., MM imitation recognition; Nadel, 2002, 2004).

Observational studies report that the emergence of LM and MM imitation recognition skills occurs between 0-18 months for typically developing children (Nadel, 2004). However, while the children in the current study were older (18-93 months) than the age in which these behaviors typically emerge, not all participants engaged in both types of imitation recognition behaviors. While all participants engaged in LM imitation recognition at both time points, only some were able to engage in MM imitation recognitionat baseline (75%) and follow up (89%). The current findings parallel those indicating that children with ASD may demonstrate delays in imitation recognition (Berger & Ingersoll, 2015; Meltzoff, 2007).

A subsample of children who did not engage in MM behaviors at baseline were able to engage in MM imitation recognition behaviors at follow up. Interestingly, MM imitation recognition behaviors never occurred without LM imitation recognition behaviors, which replicates Berger and Ingersoll's findings (2013). These findings provideempirical support to Nadel's (2004) proposal that LM imitation recognition behaviors support the development of MM imitation recognition behaviors. In order to recognize and test the communicative intentions of their imitative partner during an interaction (i.e., MMimitation recognition), children must first become aware that they are being imitated (i.e., LM imitation recognition). Taken together, these findings show that while imitation recognition emerges later in development in children with ASD, it follows the same developmental sequence reported for typically developing children. However, further examination would be needed to compare the developmental trajectories of imitation recognition of children with ASD to their typically developing peers.

The second purpose of the current study was to examine the effects of imitation recognition behaviors on the development of more advanced social cognitive skills, including imitation, joint attention, receptive and expressive language, expressive vocabulary, and functional communication skills. Exploratory analyses have shown that the development of MM imitation recognition is concurrently correlated with other social cognitive skills, such as language and imitation (Berger & Ingersoll, 2013, 2015). The current study expanded on these findings by utilizing a multilevel approach to examine the predictive effects of baseline imitation recognition skills on social-cognitive skill growth.

Findings revealed that imitation recognition skills were closely related to early language skills. For example, LM imitation recognition was predictive of current receptive language skills and expressive vocabulary. Children who engaged in higher rates of LM imitation recognition scored higher on receptive language skills and were also able to say more words. These findings parallel previous work showing that gaze following and social attention play a role in early language development (Mundy & Gomez, 1998). Given that social attention is an essential component of LM imitation recognition and children in our sample were early language learners, findings suggest that engaging in LM imitation recognition may be an important component of early language development.

Furthermore, findings demonstrated that receptive language growth wasmarginally dependent on MM imitation recognition skills. Thus, children who engaged in higher rates of MM imitation recognition at baseline improved their receptive language skills more rapidly than children who engaged in lower rates of MM imitation recognition.Previous research has suggested that MM imitation recognition reflects an early understanding of communicative intentions; thus, findings suggest that recognizing the intentions of an imitative partner may support the development of understanding language(Nadel, 2002; Meltzoff, 2007).

This interpretation is supported by previous research demonstrating that intention understanding is related to social cognitive abilities (e.g., the ability to respond to joint attention) which uniquely supports receptive language growth (Meltzoff, 2007; Schietecatte, 2012; Charman, 2003). It has been shown that social cognition develops through the experience-expectant neurodevelopmental process, in which children interact with others and process information needed to understand communication and problem solve (Mundy, 2018).

Joint attention has been shown to play a role in this developmentalprocess, as it supports children’s understanding and sharing of communication and intent(Mundy, 2018). Mundy and colleagues (2018) suggested that understanding and sharingcommunication develops prior to language onset. Therefore, imitation recognition may support interactions in which children share their intents and develop a better understanding of language and communication. It is important to note that while we can’tdraw clear conclusions as to why imitation recognition was not shown to influence expressive language growth, it is hypothesized that understanding communicative intent may be more influential in understanding communication rather than producing language(Mundy, 2018).

These findings have clinical implications, as it could inform the development of intervention strategies that target imitation awareness and intention understanding in order to promote receptive language growth. Taken together, the current study may inform providers on pivotal areas to engage with during early interventions with children with ASD to address receptive language development more effectively.

The current study has various limitations that could be addressed in future examinations of imitation recognition. First, participants in the current study were enrolled as part of a larger RCT examining a parent-mediated intervention targeting social communication skills. As part of the RCT study, some participants received an intervention that may have indirectly promoted imitation recognition skills. Thus, it is unclear the extent to which improvements in imitation recognition are due exclusively to development or require direct intervention. The current study was not designed to examine the impact of this intervention on imitation recognition skills. However, future studies may examine how imitation recognition skills interact with intervention strategiesin order to support receptive language growth.

Additionally, in order to examine the use of imitation recognition as an intervention strategy, future studies may examine changesin the rate of imitation recognition behaviors before and after an intervention that targets imitation and social communicative development (Ingersoll, 2010, 2012). Further, the interaction of MM imitation recognition and time in predicting change in receptive language was only marginally significant, and a number of analyses were run which canincrease the risk of Type I errors. Thus, this result should be replicated in a larger sampleto increase confidence in this finding.

Another limitation was that the current study was not able to examine thepredictors of change in imitation production and joint attention skills over time, due to thelack of significant change in these skills in this particular sample. Imitation and joint attention have been found to be predictive of other more complex skills, such as languagedevelopment and communication (Charman, 2003; Toth et al., 2006). Therefore, understanding whether imitation recognition had an effect on the development of these skillswould help further delineate developmental trajectories of pivotal skills in children with ASD. Future studies can examine the role of imitation recognition in these skills over time.

Previous studies have shown that children with ASD respond to imitation more frequently than to other social overtures, as opposed to their typically developing peers who respond more frequently and similarly to imitation and other social overtures (Contaldo et al., 2016). While the current study shows that children with ASD increase the frequency of imitation recognition behaviors over time, there is still limited knowledgeon whether they would also increase their attention to other social overtures (parallel to their typically developing peers) or continue responding to imitation more than other social contingencies. Future longitudinal examinations of imitation recognition could incorporate a control group examining children's responses to another type of contingent socialresponse, as well as match their participants to typically developing peers.

In conclusion, this study demonstrates that children with ASD more readily understand and recognize that they are being imitated over time. Additionally, the current study replicated previous findings identifying two distinct types of imitation recognition behaviors (i.e., LM and MM) and was the first to demonstrate that imitation recognition behaviors follow a developmental sequence, with LM imitation recognition behaviors preceding MM imitation recognition behaviors. Lastly, imitation recognition behaviors support the development of receptive language abilities. The findings of the current study have the potential of informing the development of intervention strategies to support social and cognitive abilities in children with ASD.

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