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Developmental Correlates of Different Types of Motor Imitation in Young Children with Autism Spectrum Disorders

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Abstract This study used a concurrent correlational design to examine associations between three types of motor imitation with objects and three proposed correlates in 32 two- and three-year-old children diagnosed with ASD. Attention-following and fine motor ability were significant, unique correlates of imitation in an observational learning context. Attention-following was a significant correlate of imitation in a direct elicitation context. Social reciprocity was a significant correlate of imitation in an interactive play context. These associations were observed after controlling for general developmental level. Results support previous findings that motor imitation may not reflect a unitary construct for children with ASD and that different skills may underlie the performance of different types of motor imitation. Implications for interventions targeting motor imitation are discussed.

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Introduction

Motor imitation is an important component of both social and cognitive development (Uzgiris, 1981, 1999; Yando, Seitz, & Zigler, 1978). From a social perspective, imitation may be foundational for an infant's emerging ability to detect the correspondence between self and others (Meltzoff & Gopnik, 1993). According to this view, the early opportunity for an infant to detect that others are ''like me'' leads to later understanding of other's intentional behavior and the development of theory of mind (Meltzoff & Moore, 1999). In addition, imitation represents one of the earliest forms of reciprocal interaction between infant and caregiver (Nadel, Guerini, Peze, & Rivet, 1999). From a cognitive perspective, imitation has been described as a precursor to symbolic functioning (Piaget, 1962) and the development of both language and play. Developmental taxonomies of play, almost without exception, contain a stage characterized by the child's functional use of conventional objects (Casby, 2003) and this type of object knowledge is acquired through imitation. The child's production of an imitative act, whether verbal or gestural, represents an early symbol; that is, a single behavior that stands for the child's complete mental representation of an object (Bates, 1979; Bates, Thal, Whitesell, Fenson, & Oakes, 1989). Although object knowledge is, of course, acquired through the child's own nonimitative exploration of object properties, knowledge about what to do with conventional objects is acquired by watching what others do with them (von Hofsten & Siddiqui, 1993). As such, imitation has been conceptualized as a learning strategy through which infants acquire and master new behaviors (Meltzoff & Moore, 1983).

There is broad consensus that the ability to imitate the actions of other people represents a robust deficit for children with autism (Charman et al., 1997; Curcio, 1978; Dawson & Adams, 1984; DeMyer et al., 1972; Hammes & Langdell, 1981; Jones & Prior, 1985; Ohta, 1987; Rogers, Bennetto, McEvoy, & Pennington, 1996; Sigman & Ungerer, 1984; Stone, Ousley, & Littleford, 1997; Whiten & Brown, 1998). Impaired motor imitation is observed as early as 20 months of age in children who are later diagnosed with autism (Charman et al., 1997) and, despite some improvement with development (Rogers et al., 1996; Stone et al., 1997), may represent a specific and primary deficit for individuals in this population (Rogers et al., 1996; Stone et al., 1997). Motor imitation has been found to predict both language and play skills in children with autism (Charman et al., 2003; Sigman & Ungerer, 1984; Stone et al., 1997; Stone & Yoder, 2001). Indeed, many intervention strategies for children with autism rely heavily on imitative ability. Behavioral interventions, such as those employing discrete trial training (Lovaas & Smith, 2003) or video and peer modeling strategies (Charlop & Milstein, 1989; Charlop, Schreibman, & Tryon, 1983; Charlop & Walsh, 1986; Goldstein, Kaczmarek, Pennington, & Shafer, 1992; Pierce & Schreibman, 1995, 1997), have relied directly on child imitation as a means to facilitate the acquisition of intervention targets. Other more naturalistic treatment approaches have targeted imitation as a developmentally important behavior that may be pivotal for the acquisition of a variety of later emerging social communicative behaviors such as play and language (Ingersoll, 2003; Stahmer, 1995).

Although the motor imitation deficit in children with autism is well-established, some children with autism perform imitation tasks as well as some MA-matched comparison children. Additionally, there is considerable individual variability in motor imitation performance within the ASD population. Table 1 presents a group of studies of motor imitation that: (a) utilized either typically developing or developmentally delayed MA-matched comparison samples; and (b) reported means and standard deviations for their participants (Charman et al., 1997; Jones & Prior, 1985; Rogers et al., 2003; Smith & Bryson, 1998; Stone et al., 1997). A sense of the overlap and variability in the distribution of motor imitation performance for children with autism can be gained by examining the means and standard deviations reported in these studies. The question of why some children with autism demonstrate better motor imitation ability than others becomes salient in light of this within-sample variability.

One strategy for understanding individual differences in motor imitation performance is to examine predictors of motor imitation in samples of children with ASD. While theory suggests that social, attentional and motor ability all may contribute to the observed pattern of deficits, only a few published studies have attempted to explain variance in imitation performance in children with autism. In one such study, Rogers et al. (2003) reported significant bivariate associations between overall imitation ability and both social responsivity and fine motor skill. However,

Table 1 Means and standard deviations for studies examining motor imitation performance across diagnostic groups

Study	Diagnostic group		
	Autism	Developmental delay	Typical
Rogers, Hepburn, Stackhouse, and Wehner (2003)			
Total imitation	12.63 (8.2)	19.80 (7.7)	20.00 (7.6)
Object imitation	4.58 (4.2)	6.46 (4.2)	7.27 (4.0)
Smith and Bryson (1998)			
Symmetrical posture imitation	81.1 (12.9)	92.8 (7.7)	91.3 (9.7)
Asymmetrical posture imitation	73.5 (13.4)	82.5 (7.4)	80.7 (10.1)
Jones and Prior (1984)			
Gestures	15.5 (3.17)	18.5 (1.02)	19.1 (.94)
Dynamic movement	8.6 (2.53)	11.3 (.90)	11.0 (.97)
Charman et al. (1997)			
Actions with objects	.22 (.25)	.53 (.29)	.82 (.17)
Stone et al. (1997)			
Total imitation	9.8 (4.4)	17.4 (7.6)	15.2 (8.5)
Body imitation	2.6 (3.4)	6.1 (4.4)	4.1 (5.6)
Object imitation	7.2 (3.8)	11.3 (3.9)	11.1 (3.6)

neither concurrent correlate made a unique contribution to imitation performance over and above the contribution of verbal development.

Identifying predictors of global imitation performance may not provide a completely adequate approach to understanding individual differences in imitation ability, as it has been suggested that motor imitation may not represent a unitary construct for children with autism (Stone et al., 1997). In support of this notion, Ingersoll, Schreibman, and Tran (2003) recently demonstrated significant differences in performance between children with ASD and MA-matched typically developing children only when imitated actions with objects did not result in a sensory effect. Children with ASD imitated as well as comparison children when imitated actions produced a sensory reward (Ingersoll et al., 2003). Assuming that motor imitation does not represent a unitary construct for children with autism, a productive experimental strategy may focus on identifying specific abilities underlying particular types of motor imitation performance.

Motor imitation that involves actions with objects may be especially important for children with ASD because this type of imitation takes place within a triadic interaction, an important developmental context (Adamson & Bakeman, 1991). In general, imitating the actions that others perform on objects requires that children have sufficient social motivation to establish a reciprocal interaction with a social partner, sufficient attention to people to observe and follow the behavior of others, and adequate motor ability to reproduce adult actions. However, the extent to which this is so may vary depending on the type of object imitation that is measured. The purpose of the current study was to examine correlates of motor imitation with objects in several interactive contexts representative of situations typically encountered by children with ASD.

For example, motor imitation of actions with objects can be examined by having an examiner directly elicit child responses within a structured setting (direct elicitation). This is the type of imitation targeted by traditional behavioral approaches to intervention (Lovaas & Smith, 2003). Motor imitation of actions with objects also can be examined by allowing the child to observe an instrumental act prior to providing the opportunity for a spontaneous response (observational learning). This is the type of imitation targeted by interventions that employ video or peer modeling procedures (Charlop & Milstein, 1989; McGee, Almeida, Sulzer-Azaroff, & Feldman, 1992; Pierce & Schreibman, 1995, 1997). Finally, motor imitation with objects can be examined by presenting behavioral models during naturalistic social interactions (interactive play). This is the type of imitation used in developmental approaches to intervention (Greenspan & Wieder, 1998) as well as naturalistic behavioral interventions such as pivotal response training (Stahmer, 1995).

Three measures of motor imitation, each incorporating the task characteristics of one of these interactive contexts, were developed for the current study. The measures differed in the extent to which they provided a context for participants to interact with the examiner and the extent to which attention to the examiner was required either to select the target object or to reproduce the demonstrated behavior. It was hypothesized that the correlates of motor imitation performance would differ according to the unique social and cognitive demands of each of the three measures.

The construct of social reciprocity was selected as one potential correlate of motor imitation. Because the primary reward for imitation during both the direct elicitation task and the interactive play task was presumed to be social in nature, it was predicted that performance in these contexts would depend on the extent to which children were motivated by, responsive to, and/or interested in dyadic social interactions. By contrast, it was predicted that performance on the observational learning task would not require the same level of social engagement because manipulation of the target object resulted in a sensory effect that would serve as the reward for imitation performance.

Fine motor ability and visual attention-following were also predicted to be correlated with motor imitation performance. It was predicted that fine motor ability would be correlated with performance on all types of motor imitation tasks because the physical ability to perform a modeled action is a logical prerequisite for motor imitation with objects. Visual attention-following was also predicted to be a correlate of performance on all imitation tasks because of the need to attend to the specific action performed by the adult and/or the specific object selected by the adult.

This study is an initial step toward discovering which specific areas of development may be responsible for the motor imitation impairment in children with ASD. If different correlates are identified for different types of motor imitation, it will lend support to the proposal that the general construct of motor imitation should be differentiated according to the developmental domains upon which the particular types of motor imitation depend. Doing so may eventually improve our understanding of the strengths and weaknesses of young children with ASD. Given the importance of motor imitation to development and the goal of designing interventions that may mitigate the negative sequelae of deficits in motor imitation, it is necessary to focus on children with ASD as early as possible following diagnosis.

Method

Participants

Thirty-two children participated in this study. All children received a clinical diagnosis of autism (n = 22) or PDD-NOS (n = 10) from a licensed psychologist with extensive experience in the assessment of young children (W.S.). Clinical diagnoses were based on criteria provided in the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-IV-TR; APA, 2000). Diagnosis of autism spectrum disorder was confirmed for all participants according to the *Autism Diagnostic Observation Schedule—Generic* (ADOS-G; Lord, Rutter, DiLavore, & Risi, 1999).

Children were recruited from several sources: a university-based diagnostic evaluation center (n = 18), a state network providing early identification services (n = 6), parents (n = 5), or other community agencies (n = 3). Eligibility requirements for participation included: (1) existing or suspected diagnosis of autism or PDDNOS; (2) chronological age between 24 and 48 months; (3) absence of identified genetic or metabolic disorder; and (4) absence of severe sensory or motor impairment.

Average chronological age was 32 months (SD = 6.5 mos; Range = 24–46 months). Twenty-four children (75%) were under the age of three. The average mental age was 19 months (SD = 4.9 mos; Range = 12–30 mos). Fifteen of the participants were considered nonverbal as they obtained an age equivalency of under 14 months on the Expressive Language subtest of the Mullen Scales of Early Learning (*MSEL*). Fourteen months was selected as the cutoff for determining verbal status as this has been reported as the mean age at which typically developing children have 10 expressive vocabulary words (Fenson et al., 1994). All children had mothers who completed high school. Twenty six children were Caucasian and 4 children were African American. Descriptive information detailing participant characteristics for the total group and according to diagnosis (autism vs. PDD-NOS) is presented in Table 2.

Measures

The procedures, constructs and variables included in the study are summarized in Table 3 and described in detail below.

Measures of Motor Imitation

Imitation in a Direct Elicitation Context

The *Motor Imitation Scale* (*MIS*; Stone et al., 1997) was used as an observational measure of immediate,

Table 2 Participant characteristics by diagnosis (Autism N = 22, PDD-NOS N = 10)

Characteristic	Mean	*SD*	Range
Chronological age (mos)	32.38	6.8	24.0–46.0
Autism	31.59	6.49	24.0–46.0
PDD	34.10	6.81	24.0–46.0
Autism severity[a]	23.50	4.08	23.5–33.6
Autism	29.50	3.62	29.5–44.0
PDD	23.5	3.16	23.5–35.0
Mental age[b]	18.61	4.87	12.0–29.75
Autism	17.61	4.66	12.0–27.75
PDD	20.83	4.83	15.25–29.75
Visual reception[b]	22.47	4.77	14.0–31.0
Autism	21.32	4.88	14.0–30.0
PDD	25.00	3.50	18.0–31.0
Fine motor[b]	22.63	4.78	13.0–34.0
ASD	22.18	4.94	13.0–34.0
PDD	23.60	4.50	17.0–28.0
Receptive language[b]	13.63	5.72	7.0–33.0
Autism	12.55	4.50	7.0–27.0
PDD	16.00	7.51	10.0–33.0
Expressive language[b]	15.75	7.37	5.0–35.0
Autism	14.41	7.33	5.0–35.0
PDD	18.70	6.93	8.0–31.0

[a]Scores derived from the *Childhood Autism Rating Scale* (*CARS*; Schopler, Reichler, & Renner, 1999). Scores can range from 15 to 60, with higher scores indicating greater severity, and scores of 30–36 falling within the mild to moderate range

[b]Scores derived from the *Mullen Scales of Early Learning* (*MSEL*; Mullen, 1995). All scores are expressed as age equivalents, with the Mental Age score representing the average of the four subscales

Table 3 Description of constructs and variables in the study

Construct	Variables
Motor imitation with objects	
Direct elicited (*MIS*)	Raw score for *MIS* Object items attempted or passed
Interactive play	Proportion of trials resulting in exact or partial imitations
Observational learning	Number of items passed
Proposed correlates	
Attention-following	Proportion of time child attended to target objects relative to total time of completed trials
Social reciprocity (*ADOS-G*)	Social interaction algorithm score
Nonimitative fine motor ability (*MSEL*)	Raw score for the nonimitative items from MSEL Fine Motor scale
Covariate	
Developmental level (*MSEL*)	Average of age equivalency scores from MSEL Visual Reception, Receptive Language, and Expressive Language

elicited motor imitation ability. The *MIS* is administered within a structured testing situation and consists of 8 object and 8 body imitation items. The object subscale was used for this study and items included: tapping spoon on table, shaking noisemaker, walking small dog across table, walking hairbrush across table, putting block on head, putting beads around neck, pushing car across table, pushing cup across table. Only a single object is available to the child during each trial. After the examiner demonstrates the target action, the child is instructed, ‘‘You do it.’’ The child is given three opportunities to imitate each modeled action; these opportunities are presented consecutively during the trial and are not distributed across the testing session. Each item is scored pass (2), emerge (1) or fail (0) on the basis of quality and accuracy of the imitation. The score for direct elicited imitation was the raw score from the *MIS* Object subscale. The psychometric properties of the *MIS* are described in detail in Stone et al. (1997). The *MIS* has excellent interrater reliability; Cohen's κ collapsed across MIS items and participants was .80. The standardized α coefficient for the total *MIS* was .87 and test–retest reliability across a two-week period was .80.

Imitation in an Interactive Play Context

A measure to assess imitation of novel object movements in a free-play context was developed for the current study. A variety of toys, some available in duplicate, were used for this procedure. Toys included pounding peg sets (2), toy telephones (2), plastic trucks (2), bus with people (2), set of fish-shaped plastic rings (2), wooden cubes, nesting blocks, wooden ramp, and bucket of sponge balls. The materials were distributed about the room and the examiner allowed the child to play with materials of the child's choice. The examiner began the session by watching the child play, and then unobtrusively imitated the child's actions with the toys. If the child did not engage with the materials, the examiner encouraged and offered toys to the child as necessary. The actions that were modeled by the examiner were required to be actions the child had not used previously with the play materials, yet were required to be developmentally appropriate for the child. In addition, the experimenter had to use the toy with which the child was engaged just prior to the modeling.

For example, if the child were playing with a car, the examiner might roll the identical car down a ramp. If the child were stacking blocks, the examiner might drop a block into a bucket. The examiner performed the target action three times in an animated way, accompanied by vocalizations to draw the child's attention to the action. Following each model, the examiner looked expectantly at the child for 10 s, allowing the child time to respond. The first trial was accompanied by the verbal instruction, ‘‘(Child's name), Look! Do this!’’ The remaining trials were accompanied by the verbal instruction ‘‘(Child's name), Look!’’ The examiner did not provide consequences contingent on the child's imitation. At the conclusion of each trial, the examiner resumed imitating the child's play. If the child initiated an interaction with the examiner (i.e., offering a toy), the examiner responded. Because there was a finite set of toys, there were similarities in the actions modeled across children; however, there was not a set of defined actions that was presented to all children.

A research assistant cued the examiner to present the next trial after 1.5 min had elapsed. The entire procedure consisted of ten trials but was discontinued after 15 min, whether or not all trials had been presented. Twenty two participants completed all 10 trials. Six participants completed 9 trials, two participants completed 8 trials, one participant completed 6 trials and one participant completed 4 trials. The latter participants both had a diagnosis of autism and were at the younger end of the age range included. The child who completed 4 trials was 25 months old and had an MA of 16.75 months. The child who completed 6 trials was 24 months old and had an MA of 14.75 months. Both children had expressive language age scores of less than 14 months according to the *MSEL*.

This measure was coded from videotape using event coding via a paper and pencil scoring method. The child's exact and partial object imitations were coded for each completed trial. An exact imitation was coded if the child used the same object and completed the entire modeled behavior. A partial imitation was coded if: (a) the child used the same object and performed part but not all of the modeled action; (b) the child used another object and performed all of the modeled action; or (c) the child used another object and performed part of the modeled action. The proportion of trials to which children gave exact or partial imitations was used as the score for this measure.

Imitation in an Observational Learning Context

A measure to assess spontaneous instrumental imitation in an observational learning context was developed for the current study based on procedures described by Carpenter, Nagell, and Tomasello (1998). Materials included a black plastic platform (24 × 12 × 4 inches) with a panel of eight 4-inch diameter colored lights affixed perpendicular to the back of the platform. The experimenter could manually activate the lights to produce a flashing display as a reward. During each trial, a different stimulus board with three attached objects was placed on the platform. Nine different objects were used, each appearing on three boards. Each of the nine objects was selected to elicit a specific motor action (i.e., spin, roll, pull, push, turn, open, flip, slide, squeeze) and was the target object for a single trial; thus nine trials were given.

At the onset of the procedure, the examiner activated the light display to attract the child's interest. For each trial, the examiner placed a board of objects onto the platform and manipulated the target object up to three times in an attempt to insure the child attended to the action. As the examiner performed the action, the flashing lights were activated. The child was encouraged to watch but was not given any explicit instruction to imitate. After the examiner modeled the action, she moved the apparatus into the child's reach and allowed time for the child to respond. If the child spontaneously produced the modeled action on the target object, the examiner activated the lights. If the child did not respond or responded incorrectly, the lights were not activated. The score for this measure was the number of trials on which the child activated the correct switch.

Measures of Proposed Correlates

Attention-Following

The child's ability to attend to an object while being continuously directed to do so by an adult was used as the measure of attention-following. The procedure consisted of eight 30-s trials and usually took less than 6 min to administer. The child and examiner were seated approximately 24 inches apart, and the object was placed between the child and the examiner. For each trial, the examiner presented a single novel object and provided verbal and nonverbal prompts, redirecting the child's attention to the object. Strategies for redirecting and maintaining the child's attention to the target object included: (a) placing the object close to the child; (b) using child-directed speech (including labeling the object); (c) using proximal gestures (e.g., points); (d) using adult eye gaze and head turns toward the object; and (e) moving the object. Except for a few seconds when the object was being presented and removed, the object was located directly in front of the child and within the child's easy reach; thus this procedure involved the exclusive use of *proximal* and not distal gestures. The object stimuli were constructed by gluing together a variety of small wooden shapes. Each object was 5–7 inches tall and attached to a 4-inch diameter wooden base.

The procedure was videotaped and coded to determine the duration of child visual attention to each object. Videotapes of the procedure were converted into digital format and coded using ProcoderDV (Tapp, 2003), a software system that allows accurate frame-by-frame collection of observational data from digital media. The mean length of time that the children looked at the target objects during each individual trial was 11.01 s (SD = 5.0 s, range = 2.54–19.88 s). The length of time an object was presented during each trial sometimes varied from a consistent length due to child behavior issues. The mean length of each attention-following trial was 22.9 s (SD = 3.9 s, range 13.9–33.6 s). A proportion metric was used for the attention-following variable because a preliminary analysis confirmed that trial duration was positively correlated with duration of object attention, $r(32) = .36$, $P < .04$, two-tailed. That is, children who had longer trials looked longer at the objects. In order to control for unequal trial lengths, we computed a measure that represented the proportion of time spent looking at the objects across all trials. The proportion was computed for each child using cumulative duration that the child looked at all the objects as the numerator and total duration of the trials for that child as the denominator.

Social Reciprocity

The sum of the algorithm items (converted to scores of 0, 1, or 2) from the Reciprocal Social Interaction scale of the ADOS-G (Lord et al., 1999) was used as the measure of social reciprocity. The ADOS-G is an observation scale in which the examiner creates specific semi-structured situations to observe the child's social, play and communicative behaviors. All children in this study received ADOS-G Module 1. The items that contribute to the social interaction algorithm include: unusual eye contact, facial expressions directed toward others, shared enjoyment in interaction, showing, spontaneous initiation of joint attention, response to joint attention, and quality of social overtures. Because the ADOS-G social algorithm is a deviance score, this variable was reverse scored so that the direction of prediction for this variable would be consistent with that of the other variables.

Nonimitative Fine Motor Ability

The raw score for the nonimitative fine motor items of the Mullen Scales of Early Learning (*MSEL;* Mullen, 1995) was used as the metric for fine motor ability. The *MSEL* is a standardized measure of cognitive functioning that is appropriate for children aged 3 months to 68 months. The five subscales of the *MSEL* include: Gross Motor, Fine Motor, Visual Reception, Expressive Language and Receptive Language. The Gross Motor scale was not administered for the current study.

The Fine Motor subscale of the *MSEL* contains items in which the examiner models the target behavior for the child. Including these imitative items in the measure of fine motor ability for the current study would have produced inflated associations with imitation. Therefore, only the nonimitative items from the Fine Motor scale—determined by consensus of the authors—were used. These items included: bangs in midline, puts blocks in and out, turns pages in book, puts pennies in slot, stacks blocks vertically, unscrews/screws nut and bolt, strings beads.

Covariates of Motor Imitation

Developmental Level

The proposed correlates of motor imitation are all variables that change with development, making it reasonable to predict that the correlates would also covary with mental age. Statistically controlling for mental age while examining the association between the potential correlates and motor imitation may clarify the specific aspects of development that contribute to children's ability to engage in particular types of motor imitation with objects.

The metric for developmental level was obtained by averaging the Visual Reception, Receptive Language, and Expressive Language age equivalents from the *MSEL* (Mullen, 1995). In order to examine the relation of fine motor ability to motor imitation while controlling for developmental level, it was necessary to exclude the contribution of fine motor ability. In the current study, the metric of developmental level used as a covariate in all analyses was the average of the three Mullen subtests listed above and did not include the Fine Motor scale.

Reliability

Interobserver reliability was calculated using intra-class correlation coefficients for the coded variables (i.e., the attention-following and interactive play imitation variables). Reliability coding was conducted on a random sample of 20% of the attention-following and interactive play sessions. The intra-class correlation coefficients were .96 and .93 for attention-following and interactive play imitation, respectively.

Results

Mean values of the study variables for all participants are presented in Table 4.

Associations between Proposed Correlates and Motor Imitation Measures

Zero order correlations between each of the three motor imitation measures and the proposed correlates were computed using multivariate permutation tests in order to control for multiple significance testing (Yoder, Blackford, Waller, & Kim, 2004). The measure of directly elicited motor imitation was positively related to

Table 4 Mean values of study variables for all participants (N = 32)

Variable	Mean	*SD*	Range	Potential range
Predictors				
Social reciprocity	9.75	2.82	4–14	0–14
Attention-following	.47	.20	11–.80	0–1.0
Nonimitative fine motor ability	16.66	1.91	13–19	0–28
Types of motor imitation				
Direct elicited	6.09	4.67	0–16	0–16
Interactive play	32.22	26.70	0–90	0–90
Observational learning	3.81	2.42	0–9	0–9

all three proposed correlates: attention-following, social reciprocity, and nonimitative fine motor ability. The measure of motor imitation during interactive play was positively related to social reciprocity. Finally, the measure of motor imitation during observational learning was positively related to both nonimitative fine motor ability and attention-following.

Associations between Proposed Correlates and Motor Imitation Measures, Controlling for Developmental Level

When controlling for developmental level (i.e., the *MSEL* mental age score exclusive of fine motor ability), partial correlations between the proposed correlates and the imitation measures were predicted to be positive and one-tailed tests were used. These partial correlations revealed that directly elicited imitation remained significantly correlated with attention-following, that imitation during interactive play remained significantly correlated with social reciprocity, and that imitation during observational learning remained significantly correlated with both nonimitative fine motor ability and attention-following. As predicted, all associations were positive. Zero order and partial correlation values are presented in Table 5.

When controlling for developmental level and the other correlate in separate multiple regression analyses, both nonimitative fine motor ability, $t(28) = 1.86$, $P < .04$, one-tailed, $sr^2 = .08$, and attention-following, $t(28) = 1.83$, $P < .04$, one-tailed, $sr^2 = .08$, accounted for unique variance in motor imitation during the observational learning task. When considered together in one regression analysis, attention-following and nonimitative fine motor ability accounted for an additional 16% of the variance in motor imitation performance, over and above the measure of developmental level.

Intercorrelation Among the Three Types of Motor Imitation

The degree to which the three types of motor imitation are intercorrelated sheds light on whether they are measures of the same construct. Directly elicited imitation was related to imitation during both observational learning, $r(31) = .63$; $P < .001$, and interactive play, $r(31) = .49$; $P = .005$. Motor imitation during observational learning was also related to motor imitation during interactive play, $r(31) = .38$; $P = .03$.

Discussion

Each of the proposed developmental correlates was associated with at least one type of object imitation, even after controlling for mental age. Moreover, different developmental correlates were found for different types of motor imitation. The pattern of

Table 5 Zero-order correlations of proposed correlates with measures of motor imitation and partial correlations controlling for developmental level

	Types of motor imitation					
	Direct elicited		Interactive play		Observational learning	
	Zero order	Partial	Zero order	Partial	Zero order	Partial
Nonimitative fine motor ability	.41**	.01	.19	–.11	.50**	.32*
Social reciprocity	.44**	–.14	.58**	.45**	.15	.10
Attention-following	.49**	.31*	.20	.00	.44**	.32*

*$P < .05$, **$P < .01$; All P values determined using multivariate permutation tests

partial correlations suggests a high degree of specificity for the observed associations as the nonsignificant associations were close to zero. Attention-following was related to performance on directly elicited imitation, attention-following and nonimitative fine motor skill were associated with performance on observational learning imitation, and social reciprocity was associated with imitation during interactive play.

Because this study employed a concurrent correlational design, the directionality of the relation between developmental abilities and imitation performance cannot be determined. Although it is possible that the ability to follow the attention of others contributes in a causal way to performance on the elicited imitation task, for example, it is equally possible that variance in motor imitation has a causal effect on attention-following, or that the relation between these variables is bidirectional. Untangling the directionality of effects will require future research in this area. In the interest of stimulating future research and dialogue, however, we present explanations that posit both types of abilities as potential causal influences on one other.

After controlling for developmental level, both nonimitative fine motor ability and attention-following accounted for unique variance in instrumental motor imitation performance during an observational learning activity. Taking the perspective that this type of imitation may facilitate fine motor development and attention-following, we propose that children who engage in observational learning develop more proficient fine motor skills via their imitation of others' actions on objects. The same children may come to follow adult's attentional cues because they have discovered that doing so improves their efficacy in producing interesting environmental effects through object manipulation.

During each trial of the observational learning task, the child was presented with three potential target objects. Manipulation of only one of the objects resulted in the rewarding light display. Taking the perspective that attention-following may function as the causal variable, we propose that attention-following during the observational learning procedure enabled the child to efficiently select the object on which to act. To understand how nonimitative fine motor ability could facilitate spontaneous motor imitation, it is useful to note that the objects had been selected for inclusion in the observational learning task based on each object's likelihood of eliciting one action. The objects were attached to the display platform, placing an additional constraint on how each object could be activated. Once the correct object had been located, the affordance provided by the object may have been sufficient to guide the child's action provided that the child had sufficient fine motor ability or object familiarity to perform the action.

Although Rogers et al. (2003) also found a significant bivariate correlation between fine motor ability and a combined imitation score, they did not observe this association after controlling for verbal developmental level. One reason for this difference between the two studies may be the metric of fine motor ability used. Although the fine motor measure used in both studies was taken from the fine motor subscale of the MSEL, the current study excluded imitative items and used the raw score of the remaining fine motor subscale items rather than an age equivalency score based on all the items in the subscale. In addition, while the current study found an association between fine motor ability and instrumental imitation with objects, the outcome measure of motor imitation used by Rogers et al. (2003) was a measure that collapsed across oral–facial, object, and manual imitation items.

After controlling for developmental level, directly elicited motor imitation was positively and significantly associated with attention-following. Taking the perspective that directly elicited imitation has a causal influence, we propose that children who find object manipulation reinforcing may learn to attend to what adults are doing with objects so that they can perform a similar action. Children who engage in elicited imitation may generalize the ability to follow into an adult's focus of attention and subsequently learn to respond to other adult attentional cues. Taking the perspective that attention-following may function as the causal variable, we propose that the ability to follow adult attentional cues may facilitate directly elicited imitation by allowing the child to identify the modeled action. Only one object was available to the child during each trial of this task, but the required action could not be determined from prior object knowledge or by reacting to the affordances of the target object. Attending to the adult was necessary to identify the action to be imitated in the directly elicited imitation task.

The generalizability of the finding that attention-following is related to motor imitation is supported by the findings of an intervention study using a modified version of pivotal response training with four preschool aged children with autism (Whalen, 2001). Whalen (2001) observed increases in motor imitation performance after targeting both attention-following and initiating joint attention behaviors in a training protocol. In addition, Ingersoll (2003) observed increases in attention-following after implementing a naturalistic behavioral intervention targeting motor imitation with objects. Both of these treatment studies support the generalizability of the current finding that attention-following is positively related to the ability to imitate actions with objects.

One obvious question concerns why nonimitative fine motor ability was a significant correlate of imitation during observational learning but was not during directly elicited imitation. Although it is always more difficult to explain nonsignificant associations than significant ones, proposing an explanation may help us understand how these types of imitation differ. Perhaps object manipulation during the observational learning task required more precise hand and finger movements than did object manipulation during the elicited task. For example, the former task required specific actions such as flipping a switch, twirling a propeller, or twisting a handle, while the latter task required movements such as shaking a rattle, placing a block on head, or pushing a car across table. In addition, only a single child response was allowed during the observational learning task, possibly making this task a more rigorous measure of fine motor ability.

After controlling for developmental level, imitation during the interactive play task was positively and significantly correlated with social reciprocity. We propose that children who interact socially by imitating others may elicit more frequent social experiences that, in turn, facilitate the development of other social interactional skills. Alternatively, it may be that children who engage in reciprocal social interactions with adults may have greater motivation to interact with others. Such social motivation may result in greater frequency and accuracy of motor imitation in a naturalistic context. Although Rogers et al. (2003) also found a significant bivariate correlation between social reciprocity and a combined imitation score, social reciprocity did not account for unique variance in predicting imitation after controlling for verbal developmental level. Once again, it is possible that the difference between the two studies may be attributed to the combined motor imitation measure used by Rogers and colleagues as compared with the measure of interactive play imitation used in the current study.

Because attention-following was related to two of the three types of imitation, the absence of a significant association with imitation during interactive play is salient. We have proposed that attention-following may be important for motor imitation because it helps the child identify both the modeled action and the target object. In the interactive play task, the adult followed the child's lead by acting on an object identical to one the child was already touching. In this task, then, the child could successfully imitate an adult model without relying on attention-following to identify the target object. In addition, modeling actions appropriate for the child's developmental play level may have reduced the cognitive processing load. As a result, the child may not have needed to attend very carefully to the details of the action to get at least partial credit for a trial.

The moderate to strong positive intercorrelation among the three types of imitation suggests that these types of motor imitation represent overlapping constructs. However, it appears that imitation during observational learning is more similar to directly elicited imitation than to imitation during interactive play. First, there is a stronger (albeit nonsignificantly so) association between the former pair of imitation variables than the latter pair. Second, attention-following is a unique correlate of both observational and elicited imitation, but not of interactive play imitation. Finally, social reciprocity is a unique correlate only for imitation during interactive play.

Limitations

The current study had several limitations. Small sample size limited our power to detect possible significant effects. In addition, the study did not include a control group of typically developing or developmentally delayed children. Therefore, it is unknown whether the correlates of object imitation identified in the current study are unique to children with autism, or are related to object imitation skills in all children. In addition, this study used a concurrent correlational design. Like any such design, associations could occur because of unmeasured third variables and direction of effect is not possible to determine from such data. Future research is warranted to continue to examine these unresolved questions.

Future Directions

The present study demonstrated that attention-following, nonimitative fine motor ability and the ability to reciprocally engage with a social partner were each associated with at least one type of motor imitation in children with ASD. Longitudinal correlational and experimental studies of these associations are needed to improve our ability to determine whether these associations represent causal associations and, if so, to identify the direction of effect. Ultimately, we may find that there are bidirectional effects such that nonimitative and imitative abilities enable each other over time. Additionally, replication studies are needed to determine whether these associations are representative of the population of young children with ASD.

If future studies find the associations replicate, the pattern of results supports differentiating imitation within a naturalistic play-based context from the other two types of motor imitation. This distinction may have theoretical and clinical consequences. For example, we would not necessarily expect teaching imitation of instrumental actions within a context of observational learning to generalize to imitation performance within a more interactive, play-based setting. Additionally, we may find that different types of motor imitation have different strengths of association with later language and other social communication skills. We may need to target directly the type of motor imitation that we want to improve or teach the type of imitation most closely related to the developmental correlates we wish to support. Depending on the direction of influence, for example, targeting motor imitation within an unstructured, naturalistic context may be an effective way to scaffold the development of reciprocal social skills. However, we would not expect teaching instrumental imitation to facilitate the development of reciprocal social skills. Finally, the suggestion that an intervention broadly targeting imitation can have an effect on other social communication skills (Ingersoll, 2003) reinforces the importance of identifying the correlates of motor imitation with objects in young children with autism.

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