

Imitation performance in toddlers with autism and those with other developmental disorders

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Background: The present study sought to examine the specificity, developmental correlates, nature and pervasiveness of imitation deficits very early in the development of autism. **Methods:** Subjects were 24 children with autism (mean age 34 months), 18 children with fragile X syndrome, 20 children with other developmental disorders, and 15 typically-developing children. Tasks included manual, oral-facial, and object oriented imitations, developmental measures, joint attention ability, and motor abilities. **Results:** Children with autism were found to be significantly more impaired in overall imitation abilities, oral-facial imitation, and imitations of actions on objects than children in all of the other groups. Imitation skills of young children with fragile X syndrome were strongly influenced by the absence or presence of symptoms of autism. For children with autism, imitation skills were strongly correlated with autistic symptoms and joint attention, even when controlling for developmental level. For comparison groups, imitation was related to other developmental abilities including play, language, and visual spatial skills. Neither motor functioning nor social responsivity accounted for a significant amount of variance in imitation scores, when controlling for overall developmental level, which accounted for much of the variation in imitation ability. **Conclusions:** Simple imitation skills were differentially impaired in young children with autism, and lack of social cooperation did not account for their poor performance. In autism, imitation skills clustered with dyadic and triadic social interactions and overall developmental level, but were not related to play or language development. For comparison children, all these areas were inter-related. Hypotheses about a specific dyspraxic deficit underlying the imitation performance in autism were not supported. **Keywords:** Autistic disorder, developmental delay, motor skills, imitation, fragile X syndrome, dyspraxia.

Imitation of other people's actions is an emergent skill in newborns (Meltzoff & Moore, 1989) that elaborates considerably across the first two years of life (Hanna & Meltzoff, 1993; Kaye & Marcus, 1991; Kuczynski, Zahn-Waxler, & Radke-Yarrow, 1987; Masur & Ritz, 1984; Piaget, 1962). While some have viewed infant imitation as akin to fixed action patterns rather than intentional, volitional behavior, current evidence supports early imitation as 'effortful and voluntary' (Butterworth, 1999). Infant imitation appears to serve several functions (Trevvarthen, Kokkinaki, & Fiamenghi, 1999; Nadel, Guerini, Peze, & Rivet, 1999). The earliest function of imitation involving body movements, vocalizations, and facial expressions provides a sense of connectedness, mutuality, and a means of communication with social partners (Meltzoff & Gopnik, 1993; Nadel et al., 1999; Trevvarthen et al., 1999). A second function, beginning midway through the first year of life, provides the child with information about people's actions and intentions *vis-à-vis* the physical and social world, allowing for social learning through imitation (Uzgiris, 1981, 1999; Kugiumutzakis, 1999). It also provides a foundation for early peer interactions (Nadel & Peze, 1993; Trevvarthen et al., 1999). The role of imitation in emotion sharing is supported by the work on emotional contagion, which provides additional theory and evidence on the role of imitation in rapid sharing of emotional states across the lifespan (Hatfield, Cacioppo, &

Rapson, 1994). Motor imitation may serve as a gateway for experiencing a lifelong sense of connectedness with other people, a foundation for shared experiences of activities, emotions and thought (Stern, 1985).

Recent discovery of 'mirror neurons' in nonhuman and human primates has provided the most explicit biological mechanism yet for imitative behavior in humans (di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992). These neurons are activated when a certain movement is performed by the animal, and also when the animal sees another primate carry out the same movement (Iacoboni et al., 1999). Thus, these neurons may provide a way of sharing meaning and perceiving 'self-other correspondences'. The location of these neurons in the equivalent of Broca's area has led Rizzolatti and Arbib (1998) to suggest that the shared meanings that form the basis of communicative movements, gestures, and speech all originate from the firing of these mirror neurons. Findings from a recent fMRI study suggest that at least two brain regions are involved in human imitation: Broca's area in left inferior frontal cortex, perhaps involved in establishing meaning, and an area in right parietal cortex, which is suggested to code the kinesthetic aspects of the movement (Iacoboni et al., 1999).

Difficulty with imitation of other people's movements appears to be particularly affected in autism. Autism is defined by the presence of three main

symptom sets involving abnormalities of social reciprocity, communication and language function, and the presence of abnormally restricted and repetitive behaviors and/or interests (American Psychiatric Association, 1994). The lack of social and emotional reciprocity (or mirroring) in autism is particularly striking and, unlike motor stereotypies and repetitive behavior, is unique to the disorder. Problems with imitation discriminate children with autism from those with other developmental disorders as early as age 2 (Charman et al., 1997; Stone, Ousley, & Littleford, 1997), and continue into adulthood (Rogers, Bennetto, McEvoy, & Pennington, 1996). Several reviews of the imitation literature in autism cover the empirical studies of imitation abilities in autism carried out between 1972 and 1996 (Rogers et al., 1996; Rogers & Bennetto, 2000; Rogers & Pennington, 1991; Smith & Bryson, 1994). Studies have tended to use three kinds of tasks: actions on objects, manual and postural movements, and oral-facial movements. Persons with autism typically demonstrate impaired performance compared to controls on all three types of tasks (for some examples see Charman et al., 1997; DeMyer et al., 1972; Ohta, 1987; Rogers et al., 1996; Stone et al., 1997). The only two comparative studies that did not find autism-specific deficits had ceiling effects that may have accounted for their null results (Charman & Baron-Cohen, 1994; Morgan, Cutrer, Coplin, & Rodrigue, 1989).

Given the theoretical importance of early imitation to social-emotional development (Stern, 1985) and its impoverishment in autism, Rogers and Pennington (1991) published a review paper suggesting that the imitation difficulties in autism had not been adequately addressed by existing theories of autism. They suggested that an imitation deficit may be fundamental to the social deficits involved in autism and raised questions about the mechanisms that may be involved. Several major review papers (Meltzoff & Gopnik, 1993; Smith & Bryson, 1994) further developed ideas about the role of imitation in autism.

Nadel and colleagues (1999) have emphasized two aspects of imitation that seem particularly important in understanding autism. The first involves the importance of timing of responsive imitations in establishing reciprocity (see also Trevarthen et al., 1999). Problems with timing and coordination of imitated movements may significantly disrupt the dyadic experience. A second point involves the self messages that one receives from being mirrored by the imitating partner (Nadel et al., 1999).

Nature of the imitation impairment in autism

Several studies of imitation have explored possible mechanisms, including memory, meaning, executive functions, praxis, motor function, and intersubjectivity. Thus far, the evidence has provided support only for some aspects of motor mechanisms, par-

ticularly as it pertains to oral-facial and affective imitation. These findings will be briefly reviewed.

Memory and meaning. Several studies have explicitly examined memory for the stimuli (Bennetto, 1999; Rogers et al., 1996; Smith & Bryson, 1998). No study has reported any group difference involving the ability of subjects with autism to remember the tasks correctly over time. Additionally, subjects with autism can imitate tasks with symbolic content as accurately as tasks without such content (Rogers et al., 1996). Thus we have no evidence supporting problems with memory nor with (symbolic) meaning as underlying mechanisms.

Executive functions. A possible link between executive functions (EFs) and imitation was first suggested by Rogers and Pennington (1991) and has received only partial support. No autism-specific differences in frequency of initiation of movements were found in older adolescents (Rogers et al., 1996). While Rogers et al. (1996) found that producing sequences of tasks was relatively more difficult for higher-functioning persons with autism than for controls, this finding was not replicated by Smith and Bryson (1998), nor by Bennetto (1999). Dawson, Meltzoff, Osterling, and Rinaldi (1998) demonstrated significant correlations between executive function tasks and infant imitation tasks in preschoolers with autism. However, the size of the correlations revealed that much of the variability in imitation scores was not accounted for by EF performance. Recently, several studies have demonstrated unimpaired EF performance in young children with autism compared to controls (Dawson, Osterling, Rinaldi, Carver, & McPartland, 2001; Griffith, Pennington, Wehner, & Rogers, 1999). Thus, while executive functions may play some role in imitative skill, we lack evidence of early autism-specific group differences in EF or correlates between imitation ability and EF early in autism.

Praxis and body mapping. The idea that the imitation problem in autism might be due to dyspraxia was first suggested by DeMyer, Hingtgen, and Jackson (1981), who suggested that dyspraxia in autism was of sufficient severity to prevent the child with autism from participating in everyday nonverbal communication. Dyspraxia, and its adult counterpart, apraxia, refer to impairments in the ability to plan and execute new or complex movements in the absence of other motor symptoms (Ayres, 2000). Rogers et al. (1996) reported widespread deficits in imitation and pantomime, classic tests of praxis. The dyspraxia hypothesis in autism has been suggested by others as well, both to explain autism-specific difficulties with imitation and pantomime tasks (Bennetto, 1999; Gernsbacher & Goldsmith, in revision; Jones & Prior, 1985), and also to explain non-imitative problems with motor planning and

sequencing (Hill & Leary, 1993; Hughes, 1996; Minshew, Goldstein, & Siegel, 1997).

Examining high-functioning older children with autism and well-matched clinical controls, Bennetto (1999) found no group differences in the ability to map locations onto the body. Nor were there any differences in visual recognition memory for the movements, even after delay. The group differences in imitation involved one specific aspect of motor execution involving kinesthesia: precise reproduction of limb postures. Performance on a standard motor test revealed significant group differences and accounted for much, but not all, of the variability in imitation performance in the subjects with autism, findings also reported by Smith and Bryson (1998). Thus, motor problems in these studies were more severe in children with autism than clinical controls and partially accounted for the imitation problems.

Motor problems in autism. Motor problems have frequently been reported in autism. Damasio and Maurer (1978) described clinical motor symptoms in an early report. Kohen-Raz, Volkmar, and Cohen (1992) reported striking differences in children with autism on tasks involving standing balanced on unstable surfaces. Lack of typical hand dominance has been demonstrated (Hauck & Dewey, 2001). Manjiviona and Prior (1995) reported clinically significant levels of general motor impairments in a majority of children with diagnoses of autism or Asperger syndrome compared to test norms. Rapin (1996) reported that hypotonia, limb dyspraxia, and stereotypies were all more frequent in a group of children with autism than those with other communication problems. In some of the most intriguing reports, home video studies of infants later diagnosed with autism suggest that motor difficulties may be present very early in autism, before the first birthday (Adrien et al., 1992; Baranek, 1999; Osterling & Dawson, 1994; Teitelbaum, Teitelbaum, Ney, Fryman, & Maurer, 1998).

Social aspects of imitation. Children with autism have been shown to be responsive to the social aspects of being imitated. Nadel et al. (2000) and Dawson and Galpert (1990) demonstrated that children with autism responded with increased social initiative, orienting, and engagement after adults imitated their actions with objects. Finally, Roeyers, Van Oost, and Bothuyne (1998) tested relationships between imitation skills and joint attention behaviors in young children with autism. While imitation difficulties involving both gestural and body imitation were found in the group with autism compared to a matched control group with developmental disabilities, joint attention was more impaired than imitation in autism. Imitation skills were found to be related to both MA and CA in the children with autism but were not correlated with joint attention

behaviors, perhaps due to the complete absence of joint attention in most of the children with autism.

Is imitation a unitary skill in autism?

An intriguing finding by Stone et al. (1997) involved dissociation between imitation of actions on objects and imitation of body/facial actions in young children with autism. Furthermore, they found that body/facial imitations predicted speech development, both concurrently and longitudinally, while object imitations predicted play development. This finding is quite important because it suggests that imitation may not be a unitary phenomenon in autism.

Other findings in autism imitation studies have also reported differential effects depending on the type of task used. Both DeMyer and colleagues (1972) and Stone et al. (1999) reported that imitations of functional actions on objects were less impaired than imitation of body movements without objects. Hobson and Lee (1999) reported no autism-specific differences imitating functional actions on objects but significant impairments in imitating the emotional quality of the experimenter's movement. These general findings of better imitation of functional acts on objects fit well with the descriptions of intact cognitive understanding of means-end relationships in autism reported by Sigman and Ungerer (1984) and others.

In contrast to actions on objects, oral-facial movements are consistently reported to be severely affected in autism. Rapin (1996) reported greater oral-motor impairment in both high- and lower-functioning children with autism than with clinical comparison groups. Page and Boucher (1998), examining a group of lower-functioning children with autism (but no comparison group) on both imitative and non-imitative tasks, reported that oral-motor impairment was present in 79% of a group of children with autism, a much higher prevalence than manual (55%) or gross motor difficulties (18%). In a small comparative study, Adams (1998) reported a greater level of oral-motor difficulty in children with autism than in the CA-matched typical comparison group. Finally, two groups have reported relationships between imitation skills and speech production in young children with autism (Sigman & Ungerer, 1984; Stone et al., 1997). This relationship exists as well for typically-developing toddlers (Masure, 1995; Rodgon & Kurdek, 1977). While imitation of functional acts with objects may represent an instrumental learning function, facial imitation appears much more tied to interpersonal social engagement, including communication and mirroring of emotional expressions and imitation of sounds.

Imitation of instrumental or functional actions on objects may reflect the more cognitive apprenticeship functions of imitation and may, given the above findings, be less affected in autism.

Summary

The last few years have seen a resurgence of interest in imitation in autism, with greatly improved methods and more searching questions. The above findings suggest that imitation may not be a unitary skill in autism. Imitative performance appears to vary depending on the type of movement involved (manual actions on objects, body movements, oral-facial movements). It also appears to vary depending on the nature of the imitative task, with instrumental or functional means-end acts the least affected, and imitation of facial movements most affected. The field has moved beyond asking whether imitation is deficient in autism and is exploring more complex questions involving underlying mechanisms. Basic cognitive mechanisms involving the visual processing of modeled movements have not demonstrated impairments. Hypotheses involving autism-specific difficulties with the symbolic nature of imitation have not been supported. While some relationships between imitation and executive function exist, the lack of specific executive function differences in very young children with autism undermines a primary EF mechanism in imitation in autism. Two potential mechanisms that have some preliminary support involve motor functions, particularly praxis-related functions, and social aspects.

Many questions about imitation in autism have yet to be answered. Are different types of imitation skill relatively independent? How primary and specific is the imitation deficit to autism? What are the developmental correlates and consequences of an imitation deficit in young children with autism or other disabilities? What mechanisms lie beneath the imitation difficulty that might help us gain a greater understanding of autism?

The purpose of the present study

The present study, carried out as part of a larger longitudinal study of early development in autism, was designed to test several hypotheses:

- 1 Based on previous findings, we predict that imitation deficits are pervasive in children with autism compared to both typical and clinical control groups with their primacy reflected by relationships with key developmental areas also affected by autism: language, play, and main symptoms of autism.
- 2 Based on the work of Stone and others, we predict that children with autism will demonstrate greatest impairments in oral-facial imitations and least impairments in actions on objects relative to comparison groups. Further, we expect that specific imitation skills will support specific developments in other areas (e.g., oral imitation will be related to speech development; imitations on objects will be related to play development).

- 3 Two possible mechanisms underlying the imitation deficit seem to hold some promise: motor function, and social responsivity. Do these demonstrate particular relationships with imitation ability in early autism?

Methods

Subjects

Seventy-seven subjects were included in this study and comprised four groups: Autistic Disorder (AD; $n = 24$), Developmental Delay of mixed etiology (DD; $n = 20$), fragile X syndrome (FXS; $n = 18$), and typically-developing children ($n = 15$). The mixed group of developmentally delayed children (which contained eight children with Down syndrome) was included as a comparison, as has been the practice in previous comparative studies. Autism is generally considered to be a disorder of heterogeneous, or mixed biological etiologies, thus supporting a heterogeneous comparison group. All of the children in the clinical groups were between the ages of 21 and 50 months. Typically-developing children were between the ages of 18 and 24 months. All clinical subjects were recruited from various health and early education agencies, as well as parent support groups (e.g., Fragile X Foundation and Autism Society of America). Children with typical development were recruited from the University of Denver subject pool. The groups were quite similar in ethnic distribution and socioeconomic status (Hollingshead, 1975).

As shown in Table 1, there were no significant differences between the children with autism and those with mixed DD on chronological age, nonverbal, verbal or overall mental age. The children in the typically-developing group were comparable to the two clinical groups in nonverbal mental age and fine motor functioning, but were significantly younger than the clinical groups, and had significantly higher verbal skills than the clinical groups ($F(3, 74) = 8.72$; $p < .01$).

The children with autism were free from any other medical condition, had no visual or hearing impairment, walked by 15 months of age, had been diagnosed with autism by an outside agency, received current clinical diagnoses of autism, and met criteria for autism on at least two of three diagnostic systems: DSM-IV, ADI-R and ADOS-G.

Within the DD group, there were 8 subjects with Down Syndrome, 2 subjects with other genetic abnormalities (on chromosomes 18 and 15), and 10 subjects with developmental delays of unknown etiology. The children with DD all had normal vision and hearing, or vision corrected to within the normal range, had unimpaired hand use and were mobile. None were considered by any clinician, past or present, to have autism. None of the children in the DD group met criteria for autism on the ADI; however, two children met ADOS criteria for an autism spectrum disorder. Neither project clinician felt that either of these children had autism. These children were kept in this group because they were considered representative of the heterogeneity found in children with developmental disorders of mixed etiology. Furthermore, any bias that would be

Table 1 Subject characteristics by diagnosis

	Autistic disorder (<i>n</i> = 24)	Developmental delay of mixed etiologies (<i>n</i> = 20)	Fragile X syndrome (<i>n</i> = 18)	Typically-developing children (<i>n</i> = 15)
Chronological Age				
M (SD)	34.17 (3.6)	34.15 (6.5)	34.35 (8.3)	21.27 (1.5)
Range	26–41	24–45	21–50	18–24
Nonverbal MA				
M(SD)	23.67 (6.3)	23.58 (5.6)	21.16 (4.9)	24.13 (3.4)
Range	12–44	16–35	14–35	20–31
Verbal MA				
M(SD)	16.58 (6.7)	20.53 (5.7)	18.44 (6.8)	26.47 (4.2)
Range	5–33	11–30	8–33	19–34
Fine Motor Age Equiv.				
M(SD)	22.88 (4.6)	23.45 (5.1)	20.38 (4.2)	23.4 (3.6)
Range	13–31	17–33	14–33	18–33
Overall Mental Age				
M(SD)	20.09 (6.1)	22.04 (5.4)	19.73 (5.8)	25.3 (3.5)
Range	10–38	14–31	11–34	20–32
Gender (%)				
Male	83	45	89	40
Female	17	55	11	60
Ethnicity (%)				
Caucasian	88	80	83	86
African-American	8	0	0	0
Hispanic	0	10	11	7
Biracial	4	10	6	7
Socioeconomic Status				
M(SD)	48.3 (12.4)	53.55 (8.9)	50.74 (12.9)	48.49 (14.6)
Range	22–66	40–66	15–66	22–66

introduced by including them would be a conservative bias. It is important to note that both of these children presented with overall mental ages of less than 18 months, which has been associated with false positives on the ADOS-G (Lord, Rutter, & Le Couteur, 1994).

The children with FXS were recruited from a national parent network and specialty fragile X clinics across the country (primarily in Denver, CO; Oakland, CA; and Chapel Hill, NC). All subjects in the FXS group had normal hearing and vision corrected to the normal range, had unimpaired hand use, were mobile, and had DNA verification of fragile X status. Five of these children met criteria for autism on the ADI-R, ADOS-G, and DSM-IV checklist, as well as clinician ratings, and thus were found to have autism (Rogers, Wehner, & Hagerman, 2001). None of the remaining 13 FXS subjects met criteria on the ADOS or the DSM-IV checklist; however, two subjects did meet criteria for autism on the ADI. The clinicians determined that these children did not have the clinical syndrome of autism. The possible impact of an autism diagnosis on the FXS group's imitation scores was examined. Correlational analysis within the FXS group between Total Imitation Score and ADOS algorithm scores was significant ($r^2 = -.53$, $p < .01$), suggesting that autism symptoms were strongly related to imitation abilities. Therefore, subjects in the FXS group were treated as comprising two subgroups, fragile X syndrome without autism (FX/DD; $n = 13$), and fragile X syndrome with autism (FX/AD; $n = 5$). Owing to the small number of subjects per group, these children were included in the regression and correlational analyses, but were not included in the group comparisons by diagnosis (see below).

The typically-developing group was recruited from the subject pool at the University of Denver. All had normal hearing and vision and did not present with any

significant medical conditions. None of these children met criteria for an autism spectrum disorder on any of the diagnostic instruments used in this study.

Measures

Symptoms of autism. Autism Diagnostic Interview – Revised (ADI-R) (Lord, Rutter, & Le Couteur, 1994). The ADI-R is a structured, semi-standardized parent interview developed to assess the presence and severity of symptoms of autism in early childhood across all three main symptom areas involved in autism: social relatedness, communication, and repetitive, restrictive behaviors. The ADI-R has been carefully psychometrically validated across a wide range of ages and severity levels in autism. Dr Lord trained one author (SJR) to reliability on the ADI-R, who then trained other raters in her lab to reliability of 85% or better item agreement on three consecutive administrations using the full range of scores (0–3) rather than the truncated scoring usually used (0–2). Reliability was maintained at 85% for 20% of subjects across the period of data gathering.

Autism Diagnostic Observation Schedule – Generic (ADOS-G; Lord, Rutter, DiLavore, & Risi, 1999). The ADOS-G is a semi-structured standardized interview using developmentally appropriate social and toy-based interactions in a 30–45-minute interview to elicit symptoms of autism in four areas: social interaction, communication, play, and repetitive behaviors. The ADOS-G consists of four different modules, each directed at a particular level of language ability. In the present study, all subjects received Module 1, for pre-verbal children or those just beginning to speak.

The ADOS-G, and its predecessors, the ADOS and the PLADOS, have been carefully psychometrically validated across a wide range of ages and severity levels in autism (DiLavore, Lord, & Rutter, 1995; Lord et al., 2000). In the present study, Dr Lord trained two authors to reliability on the ADOS-G at the University of Chicago; one author (EW) then trained other raters in the lab to reliability of 85% or better item agreement on three consecutive administrations using the full range of scores (0–3) rather than the truncated (0–2) scores typically used. Reliability was maintained at 85% and checked for 20% of participants across the period of data gathering. The total score on the ADOS was used as a measure of symptom severity.

Developmental. Mullen Scales of Early Learning (MSEL; Mullen, 1989). The MSEL is a standardized developmental test for children aged 3 months to 60 months consisting of five subscales: gross motor, fine motor, visual reception, expressive language, and receptive language. The MSEL demonstrates strong concurrent validity with other well-known developmental tests of motor, language, and cognitive development. The MSEL was administered to all subjects according to standard instructions by raters with advanced degrees, trained in assessing young children with autism and other developmental disorders. Reinforcers for all subjects in all groups were used at times to reward cooperation and attention. Three sets of scores were constructed from the Mullen's. A verbal developmental quotient for each subject was constructed by averaging together the developmental age for expressive and receptive language and calculating a ratio verbal IQ (MA/CAX100); the same process was used to construct a nonverbal developmental quotient from the fine motor and visual reception scores. Finally, an overall developmental quotient was constructed in the same way, using all four of those scales.

Merrill-Palmer Scale. Two pegboards and the Seguin form board were used from the Merrill-Palmer (Stutsman, 1948) to assess the child's visual-spatial problem-solving abilities. A developmental age equivalent was calculated by averaging the developmental level of the child's performance according to test norms across the three tasks (the best of three trials each).

Vineland Scales of Adaptive Behavior, Interview Edition. The Vineland (Sparrow, Balla, & Cicchetti, 1984) is a standardized parent interview designed to assess adaptive behavior across four domains: social, communication, daily living, and motor skills. The Adaptive Behavior Composite score was used in these analyses.

Imitation Battery. The Imitation Battery was developed by three of the authors for this project (SJR, TS, and EAW). The initial battery consisted of 16 tasks (7 manual acts, 4 actions on objects, and 5 oral-facial actions). The test battery was split in half and administered on two separate days using a counter-balanced, randomized order of items. Items were administered at a table, with the child facing the adult. If the item involved an object, the child was first given

15–30 seconds to explore the object, in line with procedures by Meltzoff (1985) and others. If during this time the child initiated the target imitation item spontaneously, then an alternate action was chosen for the imitation trial; this procedure assured that the action modeled by the child was truly imitated and not the act the child would have produced spontaneously. Actions on objects were not conventional and not directly related to the affordance of the object itself. For example, the item involving a toy car involved turning the car over and patting the bottom of the toy.

A specific administration procedure was employed throughout imitation trials based on Meltzoff and Moore (1977). With the child looking directly at the adult, the examiner said '(Name), do this' and repeated the action three times rapidly in a burst of three actions each (thus demonstrating 9 rapid repetitions of the action). The child was rewarded for any attempt with social, and sometimes tangible, rewards. If the child made an imitative response to the first burst, the next task was given. If the child did not respond to the first burst, a second burst was provided (9 more repetitions in 3 sets of three). Up to three bursts were administered for each item. If the child did not perform any action after three bursts, the adult physically moved the child through the movement and then rewarded the child, in an effort to teach the child the nature of the task. No scores were recorded from these prompted trials. The first spontaneous imitation and the best imitation were scored and all coding was done from videotape. Examination of first and best performance scores revealed no significant differences; therefore, first scores were used throughout the analyses.

Scoring criteria for accuracy of each item were established based on the number of errors involved in the child's performance, with 0 reflecting no action at all, 1 reflecting a movement that appeared unrelated to the target movement, and higher scores reflecting fewer errors in the production. Errors consisted of inaccuracies like bimanual-unimanual substitutions, location of contact point on the body, and inaccurate limb position. The items and scoring criteria can be obtained from the first author. Inter-rater reliability was established prior to scoring and maintained throughout the study by having two coders independently rate 20% of the tapes. Inter-rater reliability assessed via weighted kappas ranged from .86 to .88.

Scores on 9 of the 16 items were included in these analyses (3 manual acts, 3 actions on objects, and 3 oral-facial movements). See Table 2 for imitation items. Seven items were eliminated prior to analyses due to violations of assumptions of normality. Item-by-item analysis revealed that these items were either not attempted by a majority of subjects across groups or had floor effects.

Praxis Battery. The praxis battery of seven tasks was also developed by three of the authors for this study (SJR, TS, and EW) in consultation with two expert occupational therapists. Tasks are listed in Table 2. These tasks were designed to challenge motor planning and execution abilities. Most of the tasks were not imitative; rather, the affordances of the objects themselves directed the children to perform the tasks. If the child did not attempt to complete the tasks independently, the

Table 2 Items on imitation and praxis batteries

Battery	Item
Imitation battery	
Manual items	Open and close both hands (simultaneous) Pat chest with one hand Pat elbow
Imitation: actions on objects	Pull duplos apart and bang them together Turn car upside-down and pat it Pat squeaky toy with elbow
Imitation: oral-facial movements	Extend tongue and wiggle sideways Blow cotton ball across table Make a 'noisy kiss'
Praxis battery	
	Remove a nerf ball from inside a fishbowl String large beads Put a coin in a bank with one hand Place a rod in a hole vertically Place a dangling necklace in a tall cup Climb out of a cardboard box on the floor Walk forward, pulling a pulltoy

examiner modeled, prompted and otherwise made sure the child attempted the task. Child performances were scored from videotape. Scoring criteria for each item were established based on the number of errors involved in the child's performance. Each item was scored on a four- or five-point scale, with 0 reflecting no action at all, 1 reflecting some movement that was unrelated to the target movement, and higher scores reflecting increasingly smooth, well-coordinated and accurate performance. The scoring criteria can be obtained from the first author. Inter-rater reliability was established prior to scoring and maintained throughout the study by having two coders independently rate 20% of the tapes. Inter-rater reliability calculated via weighted kappa ranged from .86 to .89.

Social responsivity score. This score was the sum of 6 ratings on ADOS that tapped dyadic social orienting and responsiveness to a partner. Item scores range from 0 (not impaired) to 3, with higher scores indicating more impairment in social functioning. Items included ratings of a child's ability to direct facial expressions to others, direct vocalizations to others, share enjoyment in an interaction, integrate eye contact with other behaviors, smile responsively, and to initiate social overtures towards others. Cronbach's alpha on the scale of 6 items was computed on a large sample of children with autism and other developmental disorders ($n = 68$), yielding an alpha coefficient of .93.

Revised Early Social and Communication Scales (ESCS, Seibert, Hogan, & Mundy, 1982; Mundy, Hogan, & Doehring, 1996). These procedures involved a 20-minute semi-structured, toy-based interaction designed to elicit nonverbal communicative behaviors involving joint attention, requesting, and turn-taking. The interaction is videotaped and coded using a micro-analytic approach. The ESCS has been

used in a number of previously published studies across various labs (see Mundy, Sigman, & Kasari, 1994; McEvoy, Rogers, & Pennington, 1993; Sigman & Ruskin, 1999). It has been found to predict language development and social relatedness in both short-term and long-term studies (Mundy & Stella, 2000). Inter-rater reliability was established at 85% and maintained throughout the project by having two raters code 30% of all tapes. The frequency of high-level Initiates Joint Attention acts (i.e., child directs the attention of the adult for the purpose of commenting by coordinating eye gaze with a distal point or other gesture to an object or event) was used in these analyses.

Modified Fewell Play Scales. The Play Assessment Scale, 5th edition (Fewell, 1992) is a developmentally-sequenced, semi-structured assessment of a child's play in both spontaneous and prompted conditions. The scale samples a wide range of both sensorimotor and symbolic play behaviors across infancy and early childhood drawn from the developmental literature and sequenced on the basis of their complexity. Construct validity of this scale has been demonstrated in a series of studies via correlations with standard developmental measures of cognition, language, and social functioning for both typically-developing and clinical samples of young children, including those with Down syndrome, low birth weight, and multiple disabilities (Fewell & Glick, 1994; Fewell, Ogura, Notari-Syverson, & Wheeden, 1997; Fewell & Rich, 1987; Folio & Fewell, 1983). Correlations with standardized cognitive, language, and adaptive behavior developmental instruments are in the .80-.92 range and are highly significant.

A modified version of this assessment, including items covering play skills from 4 to 30 months, was used in this study and administered across two lab visits. Items are ordered from easiest (targeted to 2- to 4-month-olds) to hardest (targeted to 27- to 30-month-olds), and the test is terminated once both the basal level (three consecutive passes) and the ceiling (three consecutive failures) are found. Examples of play items are: 'Grasps toy and visually examines,' 'Combines unlike but related objects together,' 'Positions objects in appropriate place then acts on the combination,' and 'Adds sounds to actions and labels to objects.' During the first visit, the examiner presented four sets of toys: (1) a construction set with vehicles, people, and building props, (2) a mealtime set with dolls, dishes and props, (3) a grooming set with brush and comb, mirror, beads, bag, and doll, and (4) a set of interesting means-end toys. The experimenter presented a set and said 'What can you do with these toys?' or 'Here are some things you can play with.' If the child did not play spontaneously, the experimenter prompted the child by either modeling specified play behaviors, or giving instructions as specified by the protocol. During the second visit, the examiner provided another opportunity for spontaneous play and then prompted additional actions with the same toy sets. The examiner scored each play item as 'spontaneous' or 'prompted' as the task was given. The total number of items in which the child exhibited spontaneous play was used in these analyses, with higher scores indicating more mature play. In this study, inter-rater agreement was examined

for over 20% of the sample and was maintained at higher than 85% item-by-item agreement.

Spatial Reversal Task (Kaufmann, Leckman, & Ort, 1990; McEvoy et al., 1993). This task assesses perseverations and set-shifting in a series of visual-spatial search tasks. The examiner sets up the task by hiding a reward under each of two identical cups behind a screen. The examiner lifts the screen and prompts the child to lift a cup, thus gaining a reward. The examiner then continues a series of trials, hiding a reward out of the child's sight underneath the same cup that the child initially had chosen, until the child has made four consecutive correct responses. Then, the side of hiding is reversed. It is expected that the child will initially choose the cup that was previously rewarded; however, when faced with absence of reward, the child will choose the alternative cup on subsequent trials and thus find the reward. The child's responses from this point forward are either correct (i.e., adjusting to the change, the child chooses the correct cup) or perseverative (i.e., the child continues to choose the incorrect cup after the initial failure trial). The examiner administers 23 trials (potential range of correct responses is 0–20) and up to four sets, reversing the side of hiding after 4 correct consecutive searches. The number of correct searches was used in these analyses.

Procedures

This study is part of a larger longitudinal study and includes measures not reported on here. The entire study was carried out under IRB approval from the University of Colorado Health Sciences Center. Consent forms were reviewed with each family and all questions were answered before consent was obtained and before any measures were gathered. Each child's mother was interviewed about her child's development and behavior using the ADI-R and the Vineland, generally at a home visit. The ADOS-G, Mullen's, imitation battery, praxis battery, ESCS, and play tasks were administered in the lab over several visits.

Results

Preliminary analyses

Development of summary scores for Imitation Battery. Consistent with previous findings on imitative ability, three subscales of imitative behavior were constructed as a function of form: Manual (acts with the hands), Object (manual actions on objects), and Oral-facial (actions with the mouth). Internal consistency was examined using Cronbach's alpha (Cronbach, 1988). Manual, Object, and Oral-facial imitation scores were combined into a total imitation score. Internal consistency yielded an alpha of .87, which was considered very good. The three imitation subscales (manual, object, and oral-facial) were similarly examined and alpha reliabilities were as follows: manual subscale score (3 items, alpha = .86), object subscale (3 items, alpha = .74), and oral-facial subscale (3 items, alpha = .86).

Partial correlations among the three subscales (controlling for overall developmental quotient) were high: manual with object ($r = .55, p < .01$); manual with oral-facial ($r = .71, p = .01$); object with oral-facial ($r = .57, p < .01$). Thus, the different types of imitation were not independent of each other.

Subject participation in Imitation Battery. The scores on the imitation battery were first examined for level of subject participation in the test procedure to make sure that findings were not influenced by a lack of response from any particular group, particularly the children with autism. For these analyses, children with FXS were collapsed into one group due to small numbers of subjects in each subgroup. Data were examined to determine whether the four groups (i.e., AD, FXS, DD, Typical) differed on their level of participation within the imitation battery. Scores were collapsed into two categories: No response (i.e., a score of 0, indicating a failure to respond to the examiner's model) vs. Attempted Response (i.e., a score of 1 or higher, indicating a contingent response to the examiner's model, regardless of the accuracy of the imitation). Using a chi-square analysis, the groups did not differ on frequency of responding to 7/9 items; however, children in the AD and FXS group responded less frequently than children with DD on two items (Elbow on toy, $\chi^2 = 8.51, p < .05$; Blow cotton ball, $\chi^2 = 9.01, p < .05$). Close examination of performance on these two items revealed that these were the most difficult tasks within the battery for children in all groups, and it was felt that poor responses to these two items reflected the level of task difficulty rather than poor cooperation. Overall, these analyses indicated that the diagnostic groups did not differ in their participation in the imitation battery.

Next, we compared the four groups on the number of modeled bursts required to elicit the first imitative response. Differences in the number of bursts might indicate difficulty encoding or processing the adult model or planning and executing the response. There were no significant group differences in the number of bursts given on manual imitations, ($F(3, 73) = 1.19, p = .32$) or oral-facial subscales, ($F(3, 73) = 1.10, p = .36$); however, there were group differences in the number of models given in the object imitation subscale by group, $F(3, 73) = 3.71, p < .05$. Specifically, children with FXS required more models to imitate items on this subscale than children with DD. Children with AD did not differ from the DD or typical group in number of models needed to perform a contingent act.

Distributions of item scores within diagnostic groups. The total imitation scores for the AD, DD, and Typical groups were fairly normally distributed; however, the distribution of scores in the FXS group was bimodal and negatively skewed. Removing the five children with FXS who also had autism improved

the normality of the distribution; thus, as previously stated, the children in the FXS group comprised two subgroups for future analysis: FXS with autism and FXS without autism.

Before including the eight children with Down syndrome (DS) into the mixed DD group, we examined the equivalence of the DD and DS groups' demographic and experimental scores. There were no significant differences in the means of imitation scores between the children with DS ($n = 8$) and the children with delays of unknown or other etiology ($n = 12$), (manual: $t = .16$, $p = .87$; object: $t = .58$, $p = .57$; oral-facial: $t = .71$, $p = .49$). In addition, demographic data on the variables shown in Table 1 for children with DS and children with DD were comparable. Thus, there did not appear to be any counter-indications for combining the two into the larger mixed DD group for greater power.

Specificity of imitation deficits to autism

The following analyses were conducted by comparing the group of 24 children with autism with the group of 20 children with DD and 15 children with typical development. A one-way analysis of variance on total imitation score revealed that children with autism performed more poorly on the imitation battery than children with DD and the typically-developing children, $F(2, 57) = 6.02$, $p < .01$. Examination of performance on subscales of the imitation battery revealed that the children with autism were more impaired than both of the other groups on oral-facial imitation, $F(2, 57) = 5.31$, $p < .01$, and object imitation, $F(2, 57) = 5.76$, $p < .01$, but not on manual imitation, $F(2, 57) = 2.24$, $p = .16$.

As seen by the mean scores in Table 3, both the typical group and the DD group are providing an imitative response as the mean response for each task on all three subscales (the lowest level imitative response = a score of 2 in each task). The median scores of the DD and typical groups revealed that on each scale, 50% or more of each group is providing an imitative response to the model. For the group with autism, the mean scores reflect that the majority of the group is responding to the experimenter's model with contingent motor responses, but less than 50% of the group is responding with an imitative response at this young age.

Children with FXS. Owing to the small and discrepant sample sizes within the two FXS subgroups based upon presence of autism, it was not meaningful to compare the means of these two groups of children; however, these data are informative in an exploratory context. See Figure 1 for the imitation scores of the two FXS subgroups, along with the AD, DD, and typical groups. The scores of the FXS with autism group (FXS/AD) are similar to those obtained for the group with AD, while the scores of the FXS without autism group (FXS/DD) are more similar to those obtained for the developmentally delayed group. Thus, the imitation deficit appears to penetrate the behavioral phenotype of children with FXS, which does not specifically include imitation deficits, who also meet diagnostic criteria for autism.

Correlations among imitation abilities and other skills

The next question concerned a replication of the findings of Stone et al. (1997) involving the roles of oral-facial imitation and imitations on objects in predicting language development and play, respectively. Partial correlations were conducted to control for overall developmental age for all 29 subjects with autism (24 from the autism group and 5 from the FX/AD group) and for 30 subjects with other developmental disorders (20 from the DD group and 10 from the FX/DD group). These included the following variables: manual imitation, object imitation, oral-facial imitation, total imitation, expressive language raw score (from the MSEL), total play score (total of spontaneous and prompted play acts from the Fewell Scale). We were also interested in the relations between imitation subscales and severity of autism symptoms as reflected in the total ADOS score, nonverbal developmental age on the Merrill-Palmer, frequency of initiating joint attention from the ESCS, number of correct searches reflecting appropriate set-shifting from the Spatial Reversal task and overall adaptive behavior age equivalent score on the Vineland. See Table 4 for correlations among these variables.

In the children with autism, both oral-facial imitation and object imitation correlated moderately and significantly with autism severity score from the ADOS and Initiates Joint Attention from the ESCS,

Table 3 Means and standard deviations of imitation performance by group ($n = 63$)

	Autism ($n = 24$)	DD ($n = 20$)	Typical ($n = 15$)	<i>F</i>	<i>P</i>	Post-hoc
Imitation Total 9 items						
Mean(SD)	12.63 (8.2)	19.80 (7.7)	20.00 (7.6)	6.02	.004	Aut < DD Aut < Typ
Manual imitation 3 items						
Mean(SD)	4.58 (4.2)	6.46 (4.2)	7.27 (4.0)	2.24	.16	Ns
Object imitation 3 items						
Mean(SD)	4.75 (2.2)	6.58 (2.2)	6.67 (1.8)	5.76	.005	Aut < DD Aut < Typ
Oral imitation 3 items						
Mean(SD)	3.29 (2.9)	5.33 (2.9)	6.07 (2.6)	5.31	.008	Aut < DD Aut < Typ

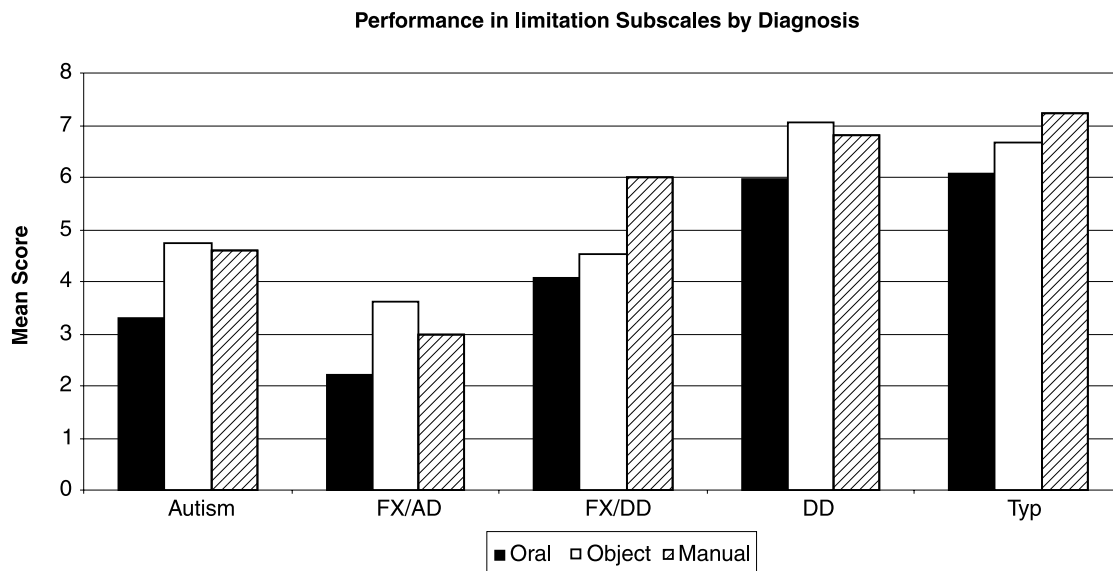


Figure 1 Imitation performance by diagnostic group

Table 4 Partial correlations among imitative skills and other developmental skills controlling for ratio IQ in children with autism ($n = 29$)

	Play	Express. language	Severity of autism (ADOS)	Initiates joint attention	Executive function	Merrill-Palmer	Vineland ABC
Manual	.08	.07	-.36	.004	.008	-.15	-.21
Object	.01	.11	-.47**	.42*	.14	-.01	-.15
Oral	.30	.27	-.64**	.38*	.02	-.02	-.09
Total	.28	.21	-.73**	.42*	.06	-.13	-.33

Partial correlations among imitative skills and other developmental skills controlling for ratio IQ in children with developmental disorders ($n = 30$)

	Play	Express. language	Severity of autism (ADOS)	Initiates joint attention	Executive function	Merrill-Palmer	Vineland ABC
Manual	.47*	.48**	-.07	-.02	.20	.27	.04
Object	.26	.42*	-.10	-.31	.41*	.40*	-.22
Oral	.09	.52**	.03	.12	.24	.20	.14
Total	.40*	.69**	-.11	.11	.32	.23	.18

but no significant relationships were found with the developmental variables. We failed to replicate Stone et al.'s (1997) finding of significant correlations between oral-facial imitations and expressive language, and object imitations and play, perhaps due to the partialling out of developmental levels in these analyses. The DD group showed a very different pattern of correlates, with all three imitation subscales correlating significantly with expressive language, and object imitations correlating also with the spatial reversal set shifting score and the visual-spatial reasoning tasks from the Merrill Palmer. Only manual imitation correlated with play skills in the DD group; thus, Stone et al.'s finding of differential correlations between types of imitation, language and play were found in the DD group but not the autism group in this study.

Possible motor and social mechanisms involved in imitative ability

Further exploration of the potential contributions of motor and social functioning on overall imitative ability was conducted using analyses of variance, correlation and regression analyses. The first analysis examined group differences on the motor and social variables. No significant group differences were found on the motor variables: fine motor functioning, $F(2, 56) = .08$, $p = .93$; gross motor functioning, $F(2, 56) = 3.03$, $p = .06$; and praxis, $F(2, 50) = .47$, $p = .63$. However, as expected, there were significant group differences in social responsiveness, $F(2, 53) = 81.24$, $p < .00$, with children with autism significantly more impaired than children in the other two groups.

To examine whether these group differences influenced the differences in imitation ability, partial correlations controlling for overall developmental age were computed for children with autism ($n = 29$) and children with other developmental disorders ($n = 30$) separately. Children with fragile X who met criteria for autism ($n = 5$) were placed in the autism group and children with fragile X who did not meet criteria for autism and had participated in all the measures ($n = 10$) were included in the DD group. Correlation analyses are displayed in Table 5. Social responsivity and fine motor skills were moderately to strongly correlated with imitation ability in children with autism. Motor variables were moderately correlated with imitation in the DD group, and social responsivity bore little relation to imitation in this group, perhaps due to restricted variability in the scores.

Upon review of these correlations, a model was constructed to test the relative contributions of social and motor functioning to imitative ability, above and beyond overall developmental functioning. Owing to its strong relationships with total imitation scores, the Fine Motor Age Equivalent was used as the index of motor functioning. It correlated strongly with the Praxis battery score ($r = .53$, $p < .01$) and was fairly independent of the Social Responsivity Score ($r = -.23$, $p = .16$).

The child's verbal developmental age from the Mullen's was entered in step 1, followed by the Fine Motor Age Equivalent score and then the Social Responsivity Score in Step 2. The verbal developmental quotient was included in the model because it was independent of fine motor scores on the MSEL, and yet was strongly correlated with nonverbal developmental ages across both groups of children ($r = .73$, $p < .01$). Thus, it served as a measure of overall developmental ability in this analysis. The regression model was tested in the two groups (autism and developmental disorders) separately, due to the potential for differential results as a function of diagnosis.

The results of the regression analyses for the children with autism are provided in Table 6. Verbal developmental ages accounted for 53% of the variance in the total imitation score. The Fine Motor Age Equivalent and Social Responsivity score added little

to the model (4%), $F(2, 26) = 1.67$, $p = .21$. These results suggest that overall developmental functioning as measured by the MSEL plays a strong role in imitation ability, while motor functioning and social responsivity do not play independent roles in imitation, above and beyond overall developmental functioning. Similar results were found for the DD group, whereby verbal developmental functioning accounted for 25% of the variance and motor and social responsivity accounted for 8% of the variance in imitation ability.

Individual differences in imitation ability within the autism group

As suggested by Dykens, Hodapp, and Finucane (2000), it is important to examine individual differences in variables of interest *within* clinical groups as well as *between* groups. We were also interested in determining how pervasive the imitation deficit was within our sample of young children with autism. Seventy-one percent (17 of 24) children with autism scored below the mean obtained for the DD group on total imitation performance, while 45% of the DD group scored below their own mean. Sixty-two percent (15/24) of children with autism scored below the mean for the DD group on Manual imitations, 88% (21/24) scored below the mean on Object imitations, and 88% (21/24) scored below the mean of DD children on Oral-motor imitations. Thus, deficits in imitation were pervasive, but not universal, in these young children with autism.

To explore the individual differences in imitation performance in children with autism, we divided the children in the autism group into two categories as a function of imitation performance. 'Strong' imitators ($n = 7$) were defined as those children whose total scores on the imitation battery exceeded the mean score of the DD group. 'Weak' imitators ($n = 13$) were defined as those children whose total scores on the imitation battery was below the mean obtained by the DD group. 'Strong' imitators obtained a mean nonverbal developmental quotient (DQ) on the MSEL of 89, whereas 'Weak' imitators obtained a nonverbal developmental quotient of 63. Verbal DQ showed similar patterns (i.e., 70 vs. 38, respectively). 'Weak' imitators presented with more severe autistic

Table 5 Correlations between motor, social, and imitation ability by diagnostic group

	Imitation total score	
	Autism ($n = 29^1$)	DD ($n = 30^2$)
Gross Motor Age Equivalent	.42	.31
Fine Motor Age Equivalent	.73**	.33
Praxis Total Score	.32	.41
Social Responsivity	-.45*	-.11

¹ 5 children with comorbid FXS.

² includes children with FXS (13) DS (7) and other dds (10).

** $p < .01$.

* $p < .05$.

Table 6 Summary of hierarchical regression analysis for variables predicting imitation ability in children with autism ($n = 29^1$)

Variable	<i>B</i>	<i>SE B</i>	<i>t</i>	<i>p</i>
Step 1				
Verbal Developmental Quotient	.46	.24	2.29	.03
Step 2				
Fine Motor Age Equivalent	.31	.37	1.45	.16
Social Responsivity	-.08	.46	-.52	.61

Note: $R^2 = .53$ for Step 1; $\Delta R^2 = .04$ for Step 2.

¹ 5 children with comorbid FXS.

symptomatology, poorer social responsiveness, and relatively impaired skills across developmental areas, with particular weaknesses in fine motor and receptive language. However, adaptive behavior and play scores were less discrepant across these two groups, suggesting that not all areas of development are equally related to imitation abilities.

Half of this group has been seen for a follow-up visit at age 4½ years. This subset of children was not significantly different from those who had not yet been seen for follow-up on any key developmental variable; however, these results should be interpreted as exploratory and preliminary until the longitudinal study is complete. See Figure 2 for a summary of the change in Developmental Quotients for Nonverbal and Verbal functioning between age 2 and age 4 on the MSEL as a function of imitation performance. Substantially more progress in both nonverbal and verbal skills was observed in the group of children who demonstrated stronger imitation skills at age two. In fact, three of the four Strong Imitators showed improvements of 10 points or more on nonverbal or verbal developmental quotients. In contrast, of the children who presented with weak imitation skills at age two, only one of six demonstrated acceleration of developmental rates in nonverbal problem solving and most demonstrated a deceleration of developmental rate over time. Again, these results must be considered preliminary and will be explored in detail in the future.

Discussion

This study sought to examine specific aspects of the imitation difficulty in young children with autism:

its nature, specificity, universality, relations with other aspects of development, and possible underlying motor and social mechanisms. Three types of imitation tasks were compared: novel actions on objects, mouth movements, and manual movements. Stringent methodological procedures and examination of children's performance were used to assure that: (1) the imitation scales were well constructed, (2) the children were carefully diagnosed and groups were well matched; and (3) group differences were not due to general lack of response on the part of the children with autism. Examination of trials indicated that the children with autism were not less likely to respond to the adult's press than the comparison children. In addition, children with autism did not require a greater number of repetitions of the model in order to attempt the task. Thus, it appears that the administrative procedures motivated all the children to respond to the adult model with contingent motor acts, and there was no indication of more refusals or less attention on the part of the children with autism.

Specificity and universality

The findings from this study replicate previous reports by Charman et al. (1997), Sigman and Ungerer (1984), Stone et al. (1997), and others in reporting robust differences in imitation performance of very young children with autism. The children in the present study were some of the youngest yet studied, with a mean age of 34 months, assessed quite near the time of first diagnosis. As a group, children with autism performed more poorly than a group of children with other developmental delays who were carefully matched on CA, verbal ability, and

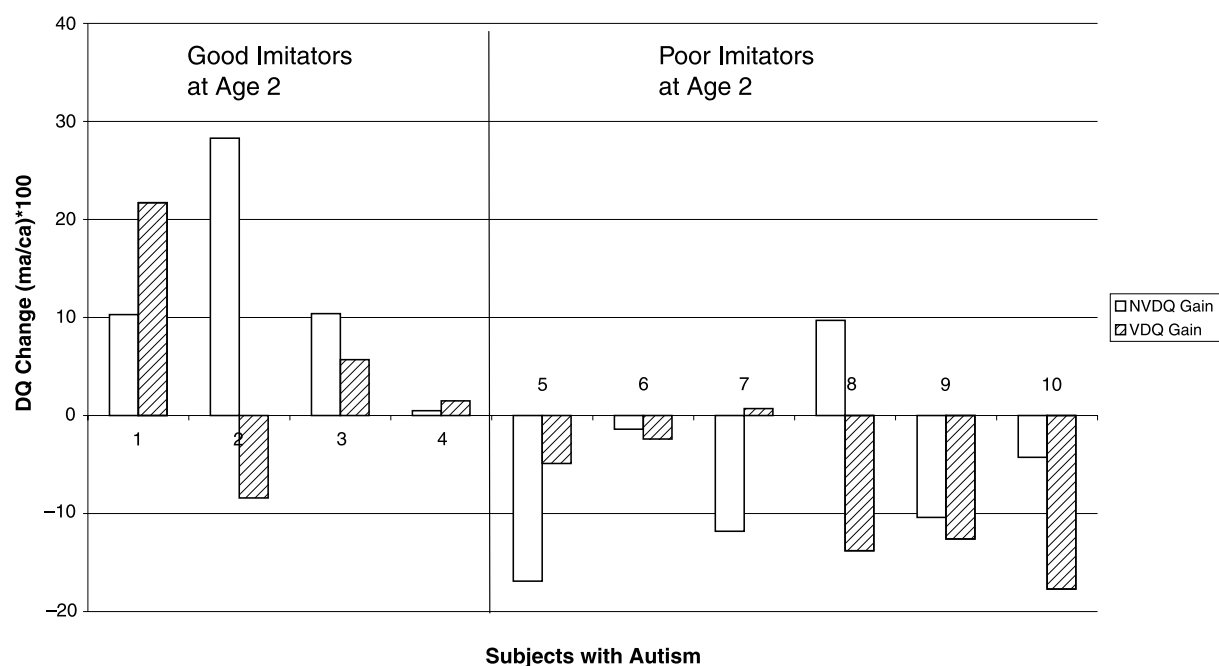


Figure 2 Change in developmental quotients from age 2–age 4

nonverbal ability. The children with autism also performed more poorly than a group of typically-developing toddlers, who as a group performed virtually identically to the developmentally delayed group on the imitation tasks, and did not differ from them on nonverbal ability or overall developmental level. Children with autism were found to have significantly poorer performance on the overall imitation scores and also on the subscale scores involving novel actions on objects and oral-facial imitations than both control groups. Their performance on manual actions was poorer than controls, but not significantly so.

This apparent specificity of the imitation difficulty to autism was further demonstrated by the performance of the children with FXS. While it has been reported that children with FXS have a relative strength in imitation skills (Hagerman, 1999), the performance of these very young children with FXS did not demonstrate an imitative strength compared to the other groups. Unlike the other diagnostic groups examined in this study, the distribution of imitation scores in the FXS group was not normal, but rather discontinuous, with imitation scores highly correlated with the presence of autism as determined by several criteria. The performance of children with FXS who did not have autism closely resembled the imitation performance of the mixed DD group, while the performance of the FXS group with autism closely resembled the imitation performance of the idiopathic autism group. This was *not* due to a confounding of imitation performance with diagnostic criteria. Of the autism diagnostic procedures that were used in this study, none of the 28 algorithm items on the ADOS involved imitation, and only 2 items out of 38 on the ADI algorithm involved imitation. Thus, imitation appeared to 'follow' autism into FXS, further demonstrating the specificity of imitation problems to autism.

However, there was considerable variability in imitation performance, with 70% of the autism group performing below the mean of the DD group. The 30% of children in the autism group with imitation skills at or above the DD mean had both nonverbal and verbal developmental scores that were much higher than the weaker imitators, with less severe symptoms of autism. Furthermore, in a preliminary visual examination of later IQ performance of 10 children for whom we had longitudinal data, three of the four strong imitators demonstrated accelerations in developmental rates for nonverbal and verbal abilities between ages 2 and 4. In contrast, only one of the six children in the weak imitative group demonstrated developmental acceleration, and half demonstrated decelerations in both verbal and nonverbal abilities. These results suggest two possible scenarios: 1) that the imitation deficit impacts negatively upon the child's ability to develop skills over time, perhaps by limiting the child's capacity to learn from natural opportunities; or 2) that a deficit

in imitation is associated with poorer cognitive functioning in general. Experimental studies involving training in imitation and other manipulations are needed in order to explore the directionality of these relationships. The importance of imitation skills to early peer engagement has been established for typically-developing toddlers (Nadel & Peze, 1993). We need studies that examine the role of imitation ability in peer interactions for children with autism. Imitative ability may not generalize easily to peers for children with autism; this may be another foundational skill to be included in early interventions.

Relationships between imitation performance and key developmental skills

Given Stone and colleagues' (1997) important report of a dissociation between oral-facial imitation and object imitation, and respective relationships with speech and play, we examined correlations among the various imitation subscales and other abilities. When we controlled for the effects of overall developmental ability on imitation scores, we did not find dissociations between these two kinds of imitation, nor did we find independent relationships between oral-motor imitation and speech development, nor between manual or object imitations and play skills.

Our lack of replication of her finding of relative independence in object imitations and body imitations may be due to differences in the tasks used. Stone's actions on objects involved familiar actions that fit the affordances of the objects used. Stone et al.'s tasks were simpler than those used in the present study, and there was no baseline condition to assure that the child would not have produced the acts even without the model. In contrast, we used novel actions on objects that contradicted the affordance of the objects. Furthermore, we used a baseline condition in which the children were already acting on the object in some way, so that imitating the adult required them to shift to a new action on the same object in response to the adult. Thus, the object imitation tasks across the two studies were not comparable, perhaps accounting for the differences found between the two studies.

For all groups of children, imitation ability was highly related to overall developmental status. In order to examine possible links between imitation and other developmental abilities, it was necessary to partial out overall developmental quotients. The resulting patterns of correlational relationships differed greatly for the children with autism as compared to the children with other developmental disabilities. For the children with autism, imitation abilities were strongly associated with joint attention abilities and severity of autism symptoms as measured by the ADOS. This finding is striking and has not been reported before. The joint attention task has no imitative elements involved, and none of the

ADOS items that make up the algorithm involves imitation. Thus, imitation difficulties appear to be a core part of the primary symptom set associated with early autism. Imitation skills were not related significantly to level of play skills, visual-spatial abilities, language development, or adaptive behavior.

A very different pattern was found for children with other developmental disabilities. All forms of imitation were associated with expressive language, and manual and object imitation skills were associated with play skills. Imitation performance was also associated with visual-motor skills and set shifting as measured by the spatial reversal task. However, it did not correlate with joint attention or autism symptoms (perhaps due to a restricted range of scores in those areas). Thus, in the DD group, imitation was closely related to other key developmental skills as well as overall intellectual ability, demonstrating the interdependence of various developmental skills that are rapidly developing in the 12–24-month period (the developmental ages of the children involved).

Does a general motor dyspraxia underlie the imitation difficulties in early autism?

We tested the hypothesis that an underlying, general difficulty with motor planning and execution might be the mechanism responsible for early imitation problems. In previous studies of imitation in autism, several groups, including our own, had reported significant correlations between general motor functioning and imitation skill, as well as a motor deficit specific to autism (Bennetto, 1999; Smith & Bryson, 1998). However, this hypothesis was not supported in the present study. The group with autism performed as well as the DD group and the typical, developmentally matched group on standardized measures of fine and gross motor performance. They also performed as well as both control groups on a set of non-imitative tasks constructed to tap motor planning and execution – the praxis battery. Imitation performance was correlated significantly with fine motor function, but not praxis (motor planning). In the regression model, overall developmental functioning accounted for the variability in imitation and motor functioning did not add significantly to the model.

These unexpected findings raise several questions. The first concerns the nature of the praxis battery. The tasks were developed by a group of occupational therapists expert in early motor development and in early autism. We wished to construct tasks that did not require children to imitate a model in order to perform the tasks, so that imitation and motor planning/execution were not confounded. The tasks derive their validity from this expert consensus, since no similar battery exists in the literature. The same experts viewed the videotapes and concurred that the tasks had high motor planning and execu-

tion demands. However, the battery may not reflect a valid measurement of this construct.

However, even if that is the case, there are no group differences on three separate measures of motor function: fine motor, gross motor, and the tasks on this praxis scale. While this appears to contradict other reports, in fact several motor studies in which children with autism are compared to children with mental retardation or other general developmental delays have reported no autism-specific general difference (Hauck & Dewey, 2001; Kohen-Raz et al., 1992; Rapin, 1996).

Finally, fine and gross motor skill level correlated with imitation performance equivalently in all three groups. Thus, a very thorough examination of motor functioning in this study did not yield evidence supportive of an autism-specific difficulty with motor coordination or generalized motor planning or motor execution. Nor did it reveal evidence of any different type of relationship between imitation and motor performance in autism than in other groups. This suggests that a mechanism other than a *generalized* dyspraxia lies behind the motor imitation difficulty in autism. However, it does not rule out a more specific motor mechanism. Our motor tasks focused on manual and body movements. The question of oral, or speech, dyspraxia was not well addressed by these findings and needs further exploration. According to theory, early imitations of oral and facial movements are crucial early social-communicative skills that lay the groundwork for further imitative development. Thus, it is theoretically possible that a specific oral-motor impairment could disrupt imitative development in general. Another type of specific mechanism could involve neurons very specialized for precise kinesthetic matching of other people's movements and postures, somewhat akin to the Eye Direction Detector (Leekam, Baron-Cohen, Brown, Perrett, & Milders, 1997).

Social mechanisms involved in imitation

Social responsivity correlated significantly with imitation performance in children with autism, but did not add to the regression model above and beyond overall developmental functioning. While we were able to establish that the children with autism appeared as responsive as others to the examiner, it is important to acknowledge the strong scaffolding for imitation provided by our procedures. It is well established that, in ongoing daily life, children with autism do not imitate others as frequently as other children and thus do not as frequently practice imitation skills. It is possible that at least some of the autism difference in imitation reflects lack of practice and resulting lack of refinement of the movements. The discrepancy between amount of imitation in scaffolded and natural situations may be due to lack of social rewards, lack of social attention to others, lack of attention shifting, or other factors.

While the core symptoms of autism are generally associated with triadic joint attention difficulties, imitation involves a dyadic, rather than a triadic, exchange. The relation between social responsivity and imitation may reflect the importance of dyadic interaction in the development of imitation abilities in young children, thus adding support to the growing number of studies demonstrating that social impairments in autism involve dyadic as well as triadic engagement (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Hobson, 1993; Osterling & Dawson, 1994). Thus, the imitation deficit in autism may best be classified as part and parcel of the broader social impairment in dyadic relations and emotional responsivity seen in autism (a position best represented by Nadel's program of research).

A final point in a discussion of possible mechanisms underlying the imitation deficit involves the role of the mirror neurons. At least two groups have suggested that mirror neuron impairment could lie at the heart of the broad social deficit in autism (Williams, Whiten, Suddendorf, & Perrett, 2001; Wolf, Gales, Shane, & Shane, 2001), affecting understanding of others' actions as well as imitation of them. A study of mirror neurons in autism spectrum disorders has already been reported (Avikainen, Kulomaki, & Hari, 1999). A difficulty with this hypothesis is the finding from several different groups that children with autism 'read' other people's intentions from their movements in means-end tasks as well as controls, an ability that would appear to require intact mirror neuron function (Carpenter et al., 2001; Aldridge, Stone, Sweeney, & Bower, 2000; Bowler & Thommen, 2000; Russell & Hill, 2001, though see Phillips, Baron-Cohen, & Rutter, 1998 for a contrary view). We need additional investigations of relationships between social-communicative and behavioral aspects of imitation and neural responses to imitative behaviors in typical and atypical development in order to develop better hypotheses concerning underlying mechanisms.

Future directions

While published studies on imitation in the past decade have firmly established the autism-specific differences, we have only begun to explore possible underlying mechanisms. People with autism carry out imitations, albeit with less precision and lower frequency than others. The clinical and empirical evidence on imitation in autism suggests that there may be more than one imitative process or mechanism involved. One candidate process or system could involve an affective mechanism modulating social exchanges with important others. This imitative process might begin with imitation of facial movements, available at birth, and develop to include affectively related body movements seen in emotional contagion and mirroring of facial expressions, body postures, gestures, and tone of voice. A

second candidate process might support an apprenticeship function. This might involve a more executively constructed, cognitively mediated, intentional imitation system that allows one to learn instrumental means-end relations from others, developing somewhat later in later infancy. This second system may function to support learning about the world of objects in relation to actions, available throughout life and seen when we intentionally imitate others in order to learn a skill from them (e.g., golf swing, a dance step). Given generally better performance imitating actions on objects, perhaps children with autism use the second, apprenticeship imitation system, but without the benefit of the first, resulting in imitations that are more effortful, less exact, and without the accompanying social/emotional markers of pleasure and intimacy that other young children demonstrate as they imitate another's movements.

This model leads to several predictions, some with preliminary support from past studies, some as yet untested. It predicts that persons with autism, compared to controls, will have more difficulty imitating the form of movements than the function of movements. It predicts more severe difficulties imitating oral-facial movements than imitating functional actions on objects. It predicts relationships between imitation of oral-facial movements, speech development, and emotional contagion. It predicts a relationship between imitating others and social/emotional relatedness to others. It also predicts gradual development of imitation abilities in autism as the second, more cognitively effortful imitation system matures. Future studies are planned to test these predictions.

Few autism studies have examined imitative performance within the natural environment; thus it is not known whether imitation performance in the lab reflects imitation skills used in daily life. Deferred imitation has not been examined yet, nor has peer imitation. Parents sometimes report that their children imitate actions hours after they were first performed, but not when they are asked to do so. Are deferred imitation skills continuous with immediate imitation skills? Finally, there seems to be a small subgroup of children with autism who, once they learn the skill of imitating motor movements, over-apply this strategy and imitate random actions out of context in a non-meaningful way (i.e., echopraxia). Is echopraxia a form of shallow processing, like echolalia, wherein the motor system is intact but the lack of social understanding compromises the adaptive quality of the response?

Given that imitation skills may be related to important outcomes for children with autism, research concerning treatment approaches for improving imitation skills, and the effect of such an approach on other areas of functioning, is relevant. Difficulties with imitation appear to be part and parcel of autism, and pursuing a deeper understanding of

imitation may lead us to a deeper understanding of the social core of autism.

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