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Interrelations Among Social-Cognitive Skills in Young Children with Autism

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Typically developing infants show a reliable developmental sequence of emergence of early social-cognitive skills, such as joint attention, communicative gestures, gaze and point following, imitation, and referential language. First infants share others' attention, then they follow others' attention and then behavior, and then they direct others' attention and then behavior. The current study used a series of tests from a study of typically developing infants (Carpenter, Nagell, & Tomasello, 1998) to investigate interrelations among these social-cognitive skills in young children with autism and children with other developmental delays. Tests of object permanence, spatial relations, facial and manual imitation, and executive function also were included. We found that for most children with autism, unlike other children, tests involving others' attention were more difficult than tests involving others' behavior. However, within the domains of attention and behavior, the typical pattern of sharing, then following, and then directing was evident. There were several positive intercorrelations among the social-cognitive skills (as there were for typically developing infants), but there also was some evidence of individual differences in patterns. Implications for theories of social-cognitive and language development are discussed.

KEY WORDS: Autism; joint attention; imitation; gestural communication; point and gaze following; language.

INTRODUCTION

During the few months before their first birthday, typically developing infants begin to show a variety of skills that seem to indicate a new level of social-cognitive understanding. These skills include joint attentional engagement, gestural communication, following others' gaze direction and pointing gestures, imitation of actions on objects, and, a little later, production of referential language. All these skills involve the coordination of attention between a social partner and an object of mutual interest, and all have been hypothesized to require a basic understanding of other people as attentional and intentional agents (Tomasello, 1995).

Carpenter, Nagell, and Tomasello (1998) explored the developmental sequence of emergence of these social-cognitive skills in a longitudinal study of 24 typically developing infants from age 9 through 15 months. They found that individual infants showed a reliable developmental pattern of emergence of these skills. They concluded that first, infants *shared attention* with adults by alternating gaze between an object and the adult in joint attentional engagement (and shortly thereafter, they shared attention somewhat more actively by declaratively showing objects to others). Then, infants *followed others' attention* by looking where they looked or pointed. Next, infants *followed others' behavior* by imitating their actions on objects. Finally, infants *directed others' attention* and then *directed others' behavior* through the respective use of distal declarative and imperative gestures such as points and reaches. Positive correlations were found

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between the ages of emergence of each pair of social-cognitive skills or their component tasks.

Two object-related skills—object permanence and spatial relations—were also tested by Carpenter *et al.* (1998) to explore whether any relations among the social-cognitive skills were due to general maturational effects of some sort. Results suggested that they were not: the object-related skills did not fit well into the developmental pattern, and few correlations were found between these skills and the social-cognitive ones. Thus, the social-cognitive skills emerge in a consistent order across infants and may belong to a relatively autonomous domain of development.

Although many researchers who study typically developing infants consider each of the social-cognitive skills discussed above to be "joint attention skills," researchers who study children with autism often use this term to refer to just a few of the skills: joint engagement (otherwise known as *referential looking*), attention following, and declarative gestures. We use that terminology here. It is well documented that the joint attention skills are selectively impaired in children with autism. Compared with children with other developmental delays, children with autism initiate fewer episodes of joint engagement (Charman *et al.*, 1997; Lewy & Dawson, 1992; Mundy, Sigman, Ungerer, & Sherman, 1986; Wetherby, Prizant, & Hutchinson, 1998) and have more difficulty following others' gaze direction and pointing gestures (Baron-Cohen, 1989; Leekam, Baron-Cohen, Perrett, Milders, & Brown, 1997). Children with autism produce imperative or requesting gestures as often as other children but they produce declarative or sharing gestures far less than do other children (Baron-Cohen, 1989; Loveland & Landry, 1986; Sigman, Mundy, Sherman, & Ungerer, 1986; Wetherby *et al.*, 1998; Wetherby & Prutting, 1984; but see McEvoy, Rogers, & Pennington, 1993; Sigman & Ruskin, 1999, for findings of fewer imperative gestures).

Deficits in the other social-cognitive skills are somewhat less pronounced. With regard to imitation, children with autism may do as well as other children on some simple tests of imitation of actions on objects (Charman & Baron-Cohen, 1994) but many studies have shown deficits on other imitation tasks (see Rogers, 1999, for a review). With regard to referential language, many children with autism never acquire any productive language. Many other children with autism do develop extensive vocabularies, but the language of these children is different in many specific ways from that of typical children (see Frith, 1989, for a review). Children with autism show little or no impairment on object-related skills such as object permanence and spatial relations (Sigman & Ungerer, 1984).

Given these findings, it is likely that children with autism show a different pattern of development than do other children, with the joint attention skills emerging after, instead of before, the other social-cognitive skills. A finding of different ordering patterns would have important implications for theories of social-cognitive and language development. Thus, one objective of the current study was to take a first step in exploring ordering relations among the different social-cognitive skills. We are aware of no previous study that has investigated such ordering relations among these skills in children with autism (although some data showing deficits in attention following and imitation but not object permanence are relevant [Gopnik, Capps, & Meltzoff, 2000]).

Another objective of the current study was to explore correlational relations among the different social-cognitive skills. There have been some previous studies of correlational interrelations among some of the social-cognitive skills in children with autism. Several researchers (Landry & Loveland, 1988; Mundy, Sigman, & Kasari, 1990; Mundy, Sigman, Ungerer, & Sherman, 1987; Sigman & Ruskin, 1999; Wetherby *et al.*, 1998) have found strong, positive correlations between children's overall joint attention scores (and individual components of those scores) and their language skills. Few relations are found between general social interaction or communicative behavior regulation (i.e., requesting/imperative) measures and language. Other studies have found correlations between imitation and verbal and gestural development (Abrahamsen & Mitchell, 1990; Curcio, 1978; Dawson & Adams, 1984; Stone, Ousley, & Littleford, 1997). What is lacking is a comprehensive study of interrelations among all the different social-cognitive (and other) skills in children with autism.

In the current study, we repeated the tests of Carpenter *et al.* (1998) with a group of young children with autism and a comparison group of children with other developmental delays. Because of difficulties in diagnosing autism at very early ages, the children we studied were not infants but instead were 3- and 4-year-olds. We thus were not able to follow them longitudinally from infancy until the skills first emerged (as Carpenter *et al.*, 1998, did) but instead tested them only once. In the Carpenter *et al.* (1998) study, the results at a single, intermediate age point produced the same ordering and correlational patterns as the overall longitudinal results. We worked under the assumption that the same would be true in the current study—that we could infer likely developmental patterns from a snapshot view of children's development (and this is the assumption that underlies each of the ordering methods we used).

METHODS

Participants

The study group consisted of 12 children with autism and 11 children with developmental delays, matched groupwise for chronological age, verbal mental age, and nonverbal mental age. Table I presents descriptive and matching information. Children were recruited from schools, treatment programs, and children's hospitals. They had been previously and independently diagnosed using *DSM-IV* criteria, and we administered the Autism Diagnostic Interview-Revised (ADI-R, Short Form; Lord, Rutter, & LeCouteur, 1995) to parents as part of the current study (see Table I for results). Diagnoses of the children with developmental delays included speech and language delays, fetal alcohol syndrome, and unspecified mental retardation.

All children participated in intervention or therapy programs of some kind, attended a special preschool, or both. Of the 10 children with autism whose parents returned a questionnaire that asked whether any treatment program in which they were involved in included work on eye contact or imitation, 7 said yes for eye contact and 6 said yes for imitation (two children with developmental delays also were working on each of these skills). Seven children with autism and four children with developmental delays were reported to be in speech therapy. Two children with autism were participating in Lovaas- or TEACCH-based programs.

Procedure

Children were brought to a university playroom for two visits within 2 weeks of each other. The Visual and Language Scales of the Mullen Scales of Early Learning (American Guidance Service, 1984) were administered during the first visit. During the second visit, data for the current study were collected. The

Table I. Participants' Chronological Age (CA), Verbal Mental Age (VMA), and Nonverbal Mental Age (NVMA) and Other Descriptive Information[a]

	Children with autism (n = 12)		Children with developmental delays (n = 11)		p (Mann-Whitney, two-tailed)
	Mean (*SD*)	Range	Mean (*SD*)	Range	
CA (in months)	48.8 (5.4)	40–57	46.0 (11.2)	31–60	.70
VMA (in months)	26.7 (9.6)	15.5–45.0	32.3 (8.3)	24.0–47.3	.17
NVMA (in months)	35.8 (7.4)	28.0–50.3	40.9 (9.2)	27.3–54.8	.21
Mother's education	Some graduate work	Some college–professional degree	Some college	Some high school–master's degree	.09
Father's education	College graduate	High school graduate–professional degree	Some college	Some high school–college graduate	.18
Family income	$40,000–50,000	$20,000–50,000+	$30,000–40,000	<$10,000–50,000+	.78
Gender	11 males, 1 female		9 males, 2 females		
Ethnicity	11 whites, 1 mixed ethnicity		8 whites, 1 black, 2 mixed ethnicity		
ADI-R[b]	11 met all 4 criteria (1 met 3 of 4)		0 met all 4 criteria (mean = 2.0; for all, 1 of these was "abnormality evident before 36 months"; 1 met 3 of 4)		

[a] Verbal and nonverbal mental ages were measured using the Mullen Scales of Early Learning (American Guidance Service, 1984) and are the averages of the Language and Visual Scales, respectively.

[b] The administrator of the ADI-R was trained to reliability to use this measure by a colleague who had been trained in Chicago. Also, the parent of one child with autism in the current study was reinterviewed 7 months later by another colleague who was trained in Chicago and excellent reliability was obtained: Cohen's kappa was .79.

procedure from Carpenter *et al.* (1998; study 1) was used, with two main modifications: (1) children were seen only once in the current study, not longitudinally (thus, only one set of objects was used), and (2) some additional tests were administered in this study. Otherwise, the procedures and the criteria for passing all except the additional tests were identical in the two studies.[5]

An experimenter (E), children, and their parent(s) sat on the floor (and a second experimenter [E2] sat in a chair) while a series of tests were administered in a predetermined, random order (with one exception: the spatial reversal test was always given last). The tests, and the other measures collected, are described below.

Sharing Attention

Joint Engagement. Videotapes of the entire testing session for this study were coded for joint engagement with E or E2. Joint engagement was scored when children spontaneously looked from an object to the adult's face and back to the same object (objects included the many, various toys played with during and between the tests). Children passed this skill if they initiated at least one such episode (joint engagement looks that were part of responses to the tests, e.g., the attention following and gesture tasks, did not count).

Following Attention and Behavior

Attention Following. For *gaze following* tests, E called the child by name, waited for eye contact, and then with an excited facial expression and vocalization (a gasp) alternated her gaze (turning her head) between the child's eyes and the assigned target (one of four stuffed animals) several times. The procedure for *point following* tests was identical with the addition that E pointed to the target. Children passed gaze or *point following* if they correctly localized the target on each of two trials (one on the left and one on the right). They passed attention following if they passed either gaze or point following.

Imitative Learning. Carpenter *et al.*'s (1998) boxes were used. For imitative learning of *instrumental actions*, there were two attachments on the top of the 30- × 30- × 16-cm box: a doorstop and a spring; the target action was lifting the doorstop. For imitative learning of *arbitrary actions*, there were no attachments on the 30- × 46- × 16-cm box; the target action was bending down at the waist and touching one's forehead to the top of the box. A set of colored lights at the back of the box lit up each time the target action was performed. After a 1- to 2-minute baseline period during which children were asked to play with the box, E modeled the target action (or if children had spontaneously performed the target action in the baseline period, E modeled an alternate action, e.g., pat or pull on the spring) three times and then encouraged the children to take a turn. Children were given approximately 1 minute to respond, and then this sequence was repeated. To determine whether children were reproducing E's action with the same goal (i.e., turning on the lights), the lights were delayed by 1 second during response periods, and we coded whether children looked in anticipation to the lights. Children passed an imitative learning test if they reproduced the modeled action with an expectant look to the lights. They passed imitative learning if they passed either the instrumental actions or the arbitrary actions test.

Directing Attention and Behavior

Communicative Gestures. Four situations were presented in an attempt to elicit production of gestures. To elicit declarative gestures, two unusual events occurred (a stuffed animal began to dance in mid-air and a puppet appeared at the door), and the adults pretended not to notice. To elicit imperative gestures, an attractive toy was placed in a locked, transparent box, and a wind-up toy was stopped. Spontaneous productions of intentionally communicative gestures (i.e., that were accompanied by gaze alternation between the object and any adult's face) were coded during these situations as well as during the rest of the session. *Declarative gesture* was scored if children produced a show, point, or give that served to direct the adult's *attention* to an object; *imperative gesture* was scored if they produced a give, point, or reach that served to request some *behavior* from the adult. Children passed communica-

[5] We were aware that some of the objects and tasks used in the original study might be less interesting to older children, and especially children with autism, so we watched very carefully for signs that this might be the case and were ready to substitute different types of objects if needed. However, our impression was that children with autism were just as likely as other children to approach and show interest in the toys. For example, they often touched the stuffed animals from the attention following tests and usually looked intently at or approached the puppets and stuffed animals in the declarative elicitation test (they just did not share this interest with others). If a child was not interested in a toy we used in the imperative elicitation test, we asked the parent for suggestions for other favorite toys. We are thus confident that our results are not merely a function of children's different interest in the objects we chose.

tive gestures if they produced either a declarative gesture or an imperative gesture.

Because most children in the current study talked often during their sessions (whereas infants in the Carpenter *et al*. study for the most part did not), we also coded imperative and declarative verbalizations that were accompanied by a look to the face of an adult. These verbalizations were treated as equivalent to gestures accompanied by looks in some analyses.

Referential Language. Children's spontaneous, nonechoed productions of referential words (i.e., words used for concrete objects or actions) were coded during the entire session. Children passed referential language if they produced at least one referential word.

Obstacle Tests

Physical Obstacle. An attractive toy (e.g., a car or ball) was placed under a transparent box. Children passed the physical obstacle test if they removed the box and obtained the toy.

Social Obstacle. One trial each of the *giving*, *blocking*, and *teasing* tests of Phillips, Baron-Cohen, and Rutter (1992) were used. Various small toys (e.g., Sesame Street figures, vehicles, tops, and balls) were used depending on the child's interests. Gaze to E's face was coded during the 5 seconds after E gave a toy to the child, suddenly blocked the child's play, or withdrew an offered object in a teasing fashion. Children passed the blocking and teasing tests if they looked to E's face during those 5 seconds. They passed the social obstacle test if they passed either the blocking or the teasing test.

Object-Related Tests

Object Permanence. A series of object permanence tests involving hiding a small toy under opaque screens (washcloths, in this case) was taken with some modifications from Uzgiris and Hunt (1975, tests 4, 12, and 14). The easiest test was administered first (E put a toy in her hand and hid it under a single screen), and if children passed that test, they moved on to the second test (E placed a toy in a cup and used the cup to put the toy under a single screen). If they passed that test, they received an invisible displacement task with two screens (E put a toy in her hand, closed her hand, and passed it under one screen, through the space between the two screens, and under the second screen, and then her hand emerged empty). If children passed that test (twice, with E's hand going through the screens in both possible orders), they received the same sort of test but with three screens. Children passed object permanence if they found the toy following one invisible displacement with two screens alternated (i.e., our third test).

Spatial Relations. Uzgiris and Hunt's (1975) spatial relations test 6 (using the relation container-contained) was used. Children were given a few minutes to play with a large cup and some wooden blocks. Children passed spatial relations if they spontaneously placed two or more blocks into the cup and removed two or more blocks from the cup during their play.

Additional Tests

Other Imitation. We included tests of two other types of imitation: imitation of manual and facial actions. For each test, E modeled two actions in counterbalanced order. If children did not reproduce E's action after the first model, up to two additional model and response periods were given. The actions for manual imitation were clap hands and open/close hand; the actions for facial imitation were open/close mouth and protrude/wiggle tongue. Children passed each type of imitation if they reproduced at least one of E's two actions after three or fewer demonstrations.

Spatial Reversal. Because previous studies have shown relations between executive function measures and joint attention skills (Griffith, Pennington, Wehner, & Rogers, 1999; McEvoy et al., 1993), we included a measure of executive function—the spatial reversal test of Kaufman, Leckman, and Ort (1989)—to investigate relations with the other social-cognitive skills. Two children with autism did not receive this test. Without these children, groups still matched on chronological age ($p = .67$) and nonverbal mental age ($p = .15$), but children with autism had a lower average verbal mental age than did children with developmental delays for these analyses ($p = .04$). E hid a small piece of food under one of two cups behind a screen, removed the screen, and asked the child to choose a cup. E continued hiding the food under the same cup until the child had chosen correctly four times in a row. Then E hid the food under the other cup, switching again after four consecutive correct trials. This was repeated for a total of 24 trials. Children passed spatial reversal if they achieved three sets (a set consists of four consecutive correct trials; five sets represents perfect performance).

Reliability

Three children from each group were selected at random. E2's live coding and E's coding from the videotape were compared for each measure except joint engagement, communicative gestures, and spatial reversal. E coded joint engagement and communicative gestures from the videotapes, and a research assistant recoded the six reliability children. For spatial reversal, the response of choosing one of two cups was unambiguous and was not checked for reliability. The mean percent agreement for all the measures was 93 (range, 75 to 100). The mean Cohen's kappa for all the measures was .81 (range = .50 [for declarative gestures; the next lowest was .67] to 1.00).

Analyses

One main objective of this study was to investigate ordering of the different social-cognitive skills. In the Carpenter *et al.* (1998) study, children were studied longitudinally so the developmental order of emergence of the various skills could be determined in two ways: (1) by comparing the mean ages of emergence of each skill and (2) by choosing a single age point and ordering the skills by the number of children passing and failing each skill at that age point. In that study, both of these methods produced the same order of skills. In the current study, children were seen just once, so only the second method could be used to infer order of emergence. We present results as if they represented patterns of emergence; however, we recognize that we are making developmental assumptions based on data from a single time point. This is the assumption that underlies each of the ordering methods we used (Bart & Airasian, 1974; Green, 1956). This assumption holds whether children are studied at the same age or at different ages, as in the current study.

Another objective of this study was to investigate correlational relations among the different social-cognitive skills. In the Carpenter *et al.* (1998) study, correlational analyses involved correlations between ages of emergence of each skill, not pass/fail scores as in the current study. For the sake of comparison, we used unpublished data from the Carpenter *et al.* study to calculate pass/fail correlations at one time point for those typically developing infants (we chose 12 months because roughly similar percentages of children in the current study and infants in that study at that age point passed the five skills as a group). We present these results here. These scores are cumulative (i.e., if an infant passed a skill at 9 months, that infant received a pass for this analysis, because if an infant passed a skill at 9, 10, and 11 months, that skill may not have been tested again at 12 months). Age of emergence and pass/fail correlations for those typically developing infants yielded very similar results (the only main difference was that communicative gestures and referential language were significantly correlated in the first type of analysis but not in the second). This again supports the assumption that relations found at one time point reflect overall developmental relations.

Whenever possible, we compare children with autism with children with developmental delays. When ceiling effects for children with developmental delays interfered with analyses, we compare children with autism with the typically developing infants from the Carpenter *et al.* (1998) study. Exact probabilities are used throughout because of the small sample sizes.

RESULTS

Group Differences

Table II presents the percentage of children from each group who passed each of the skills measured. Significantly fewer children with autism than children with developmental delays passed declarative gestures and gaze following. There were no other statistically significant between-group differences.[6]

Ordering of Skills

To find group patterns, we ordered the skills by the number of children passing each one. Equal numbers of children sometimes passed two skills so the ordering of these skills was arbitrary; in these cases, the ordering that most resembled that of the typically developing infants from Carpenter *et al.* (1998) study was chosen for analyses. For analyses that involved individual children's patterns, we inspected the array of pass/fail scores to see how many children fit the group pattern, that is, how many passed the easiest skills (the ones earliest in the sequence) and failed the harder (later) ones and did not fail easier skills while passing harder ones.

Main Social-Cognitive Skills and Their Components

Figure 1 presents the ordering of the five main social-cognitive skills for both groups of children in the current study, along with the typical developmental pattern of emergence from Carpenter *et al.* (1998) for comparison (verbalizations are not included with gestures

[6] The lack of group differences for the social obstacle test contradicts results of the original social obstacle study (Phillips *et al.*, 1992) but is in accord with findings from a more recent study (Charman *et al.*, 1997). On the spatial reversal test, as in the study by Griffith *et al.* (1999), children with autism did better than children with developmental delays, although this difference was not statistically significant.

Table II. Percentage of Children Who Passed Each Skill[a]

	Children with autism	Children with developmental delays	p
Main social-cognitive skills			
Joint engagement	75	100	NS
Communicative gestures[b]	58	82	NS
Declarative gestures	25	82	$z = 2.67, p < .01$
Imperative gestures	58	64	NS
Attention following	67	100	$z = 2.06, p < .10$
Point following	58	82	NS
Gaze following	17	100	$z = 3.94, p < .001$
Imitative learning	92	100	NS
Instrumental actions	92	100	NS
Arbitrary actions	83	82	NS
Referential language	92	82	NS
Declarative verbalization	33	55	NS
Imperative verbalization	58	64	NS
Obstacle tests			
Physical obstacle	100	100	NS
Social obstacle[c]	67	64	NS
Block	33	45	NS
Tease	33	36	NS
Give	17	9	NS
Object-related tests			
Object permanence	100	100	NS
Spatial relations	25	64	NS
Additional tests			
Manual imitation	83	91	NS
Facial imitation	67	100	NS
Spatial reversal	70	55	NS

[a] We had predicted group differences on all the joint attention skills (i.e., joint engagement, attention following, and declarative gestures), so Mann-Whitney U tests with one-tailed p values were used for these measures; two-tailed p values were used for all other measures.
[b] When gestures that were not accompanied by looks to the adult were included, all children in both groups produced at least one gesture. When verbalizations with looks were included with gestures with looks, 75% of children with autism and 91% of children with developmental delays passed this skill, and the same pattern of significant difference was found (although the group difference for declarative gestures/verbalizations was only marginally significant, $p = .09$).
[c] Marginally significantly more children with developmental delays looked to E's face following blocking than following giving, Wilcoxon $z = 2.00$, $p < .07$ (for teasing vs. giving, NS). There were no significant within-group differences for children with autism.

here, so criteria for passing are identical across studies). For children with developmental delays, there were so many ceiling effects that it was impossible to order the tasks with any confidence. For children with autism, note that the first three skills for typically developing infants were the last three for children with autism. If we exclude the three children with autism who passed all five skills (because we cannot know their order), not a single child with autism showed a pattern that was consistent with the pattern of the typically developing infants. Conversely, none of the typically developing infants who did not fit their group pattern showed a pattern like that of any child with autism: all typically developing infants passed joint engagement first and referential language last.

The pattern at the bottom of Fig. 1 is the pattern shown by the group of children with autism as a whole. To investigate whether individual children reliably followed the same pattern (as was the case with typically developing infants), a Green's (1956) scalogram analysis, a conservative measure that takes chance into account, was performed. This analysis indicated that the skills were not scalable: there was not a reliable ordering of the skills within children ($I = -.14$). Only 25% of individual children fit the group pattern exactly (not including children who passed all five skills).

Skills are ordered by the percentage of children who passed each skill (this percentage is given under each skill).

Typically-developing infants at age 12 months (from Carpenter et al., 1998)

Joint Engagement	→	Communicative Gestures	→	Attention Following	→	Imitative Learning	→	Referential Language
100		96		75		71		8

Individually, 87.5% of infants showed this pattern at age 12 months (this includes two infants – 8% – who had passed all five skills at this age.

Children with developmental delays

Joint Engagement	→	Attention Following	→	Imitative Learning	→	Communicative Gestures	→	Referential Language
100		100		100		82		82

Individually, 90.9% of children showed this pattern (this includes eight children – 73% – who passed all five skills).

Children with autism

Imitative Learning	→	Referential Language	→	Joint Engagement	→	Attention Following	→	Communicative Gestures
92		92		75		67		58

Individually, 50.0% of children showed this pattern (this includes three children – 25% – who passed all five skills).

Fig. 1. Ordering patterns of the main social-cognitive skills for each group.

To investigate ordering patterns at the level of individual pairs of skills instead of at the level of the entire sequence of skills, Bart and Airasian's (1974) ordering theoretic method was used to identify prerequisite relations between pairs of skills (i.e., pairs of skills that always follow the same order). For children with developmental delays, like the typically developing infants, there were prerequisite relations between all pairs of skills (that were not both passed by all children) except one.[7] In contrast, for children with autism, there were only four prerequisite relations (see Fig. 2 for a representation of the results of these analyses). More children passed imitative learning than joint engagement and communicative gestures (and no children passed the latter two skills but did not pass imitative learning). Similarly, more children passed referential

[7] For these children, that pair was the communicative gestures-referential language pair. Note, however, that for two other pairs (communicative gestures and attention following, and communicative gestures and imitative learning) the ordering for these children was the opposite ordering to that shown by typically-developing infants.

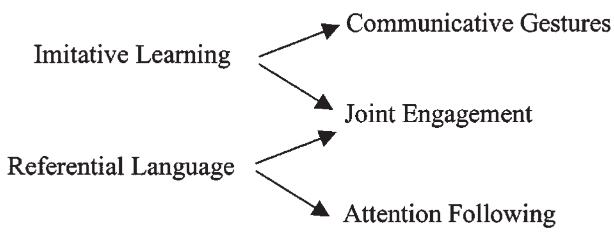

Fig. 2. Results of the ordering-theoretic-method analysis on the main social-cognitive skills for children with autism. *Note:* Lines represent prerequisite relations (with a tolerance level of zero); the direction of the arrows shows the ordering of each pair.

language than joint engagement and attention following (and no children passed the latter two skills but did not pass referential language).

The finding of fewer prerequisite relations for children with autism is consistent with the scalogram findings: these children showed more individual variation in ordering of skills than did other children. These findings also confirm the atypical ordering of some of the skills for these children, as none of the prerequisite relations followed the typical order. Similar results were found with analyses that investigated prerequisite relations between the components of the main skills, the next level down. Results are presented in Table III. Children with autism passed the components of attention following, communicative gestures, and other imitation in different orders than did children with developmental delays (although in the case of attention following, it was the latter children who passed the components in the atypical order). Thus, at all levels of analysis, children with autism showed a less consistent and a more atypical ordering of the skills and their components than did other children.

Ordering of the Main Social-Cognitive Skills by Function

Next, the skills were grouped by their function. Joint engagement, proximal declarative gestures (i.e., shows), and declarative verbalizations were categorized as sharing attention; gaze and point following were categorized as following attention; and distal declarative gestures (i.e., points) were categorized as directing attention. Imitative learning was categorized as following behavior, and imperative gestures and imperative verbalizations were categorized as directing behavior. We did not include the social obstacle test as a measure of checking behavior, as did Carpenter *et al.* (1998), because recent findings suggest that children with autism may look to E in that test for different reasons (e.g., social referencing) from those of other children (Carpenter, Call, & Tomasello, 2000).

Again, ceiling effects were a problem for children with developmental delays, as all of these children passed three of the five categories. Figure 3 presents the patterns for typically developing infants and for children with autism. Declarative and imperative verbalizations were not included for infants. Two thirds of children with autism individually fit their pattern (but it still was not scalable, $I = .16$). None of these children passed all of the categories. For these children, the pattern was different from the typical pattern in only one way: the same general pattern of sharing, following, and then directing was evident for skills involving attention and behavior separately, but skills involving others' attention were delayed compared with those involving others' behavior. For the attention skills separately, 75% of children individually followed the share → follow → direct pattern.

Ordering of Other Skills

Physical obstacle was passed by all children. Social obstacle was passed by similar percentages of children but fit later into the sequence of children with developmental delays (after referential language) than of children with autism (and typically developing infants—for both of these groups, it fit after joint engagement). Manual imitation fit after imitative learning for both groups. All children with developmental

Table III. Prerequisite Relations Between Components of the Main Skills

	Children with autism	Children with developmental delays
Attention following	Point following → gaze following[a]	Gaze following → point following[b]
Imitative learning	Instrumental → arbitrary	Instrumental → arbitrary
Communicative gestures	Imperative → declarative[b]	Declarative → imperative
Other imitation	Manual imitation → facial imitation	Facial imitation → manual imitation

[a] There was one exception to this ordering.
[b] These sequences are in the reverse order to that shown by typically developing infants (Carpenter *et al.*, 1998).

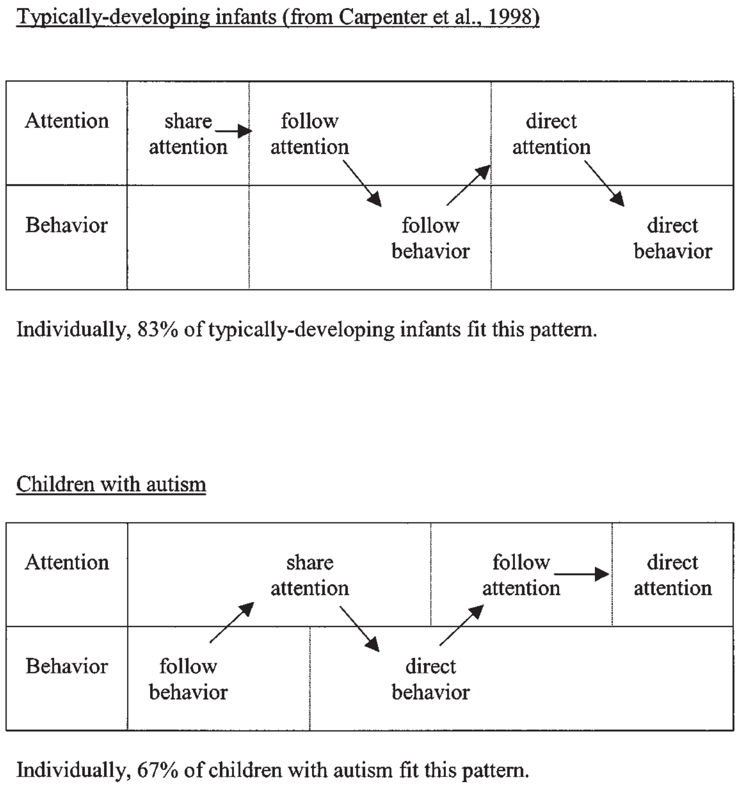

Fig. 3. Ordering by function for children with autism (and typically developing infants from Carpenter *et al.,* 1998, for comparison).

delays passed facial imitation; for children with autism, this skill fit between joint engagement and attention following. Spatial reversal fit at the end of the sequence for children with developmental delays and between joint engagement and attention following for children with autism.

Intercorrelations

There were so many ceiling effects for children with developmental delays that only one (nonsignificant) correlation coefficient was generated between pairs of the main social-cognitive skills for these children. We thus compared children with autism with the typically developing infants from the Carpenter *et al.* (1998) study. Even for these infants, there was one problem with ceiling effects: all infants had passed joint engagement by the beginning of that study, so no correlations could be obtained between joint engagement and the other skills.

Table IV presents the correlation matrix for the pass-fail scores for the five main social-cognitive skills and their components for children with autism and typically developing infants. For typically developing infants, there were many significant, positive correlations between the main social-cognitive skills or their components: five of the six pairs were correlated in some way (i.e., within each of five of the possible six gray blocks in Table IV for infants, there were one or more significant or marginally significant correlations). For children with autism, 6 of the 10 pairs were positively correlated in some way. In particular, joint engagement was positively correlated in some way with all the other skills except attention following, and referential language was positively correlated in some way with all the other skills except communicative gestures.

Unexpectedly, we also found several negative correlations for these children. The negative correlation between attention following and communicative gestures was especially strong, and point following, in particular, was negatively correlated with both declarative and imperative gestures. Another strong negative correlation was found between declarative gestures and referential language. Although this negative correlation was probably due to ceiling effects (nine children passed referential language but not declarative gestures

Table IV. Correlations Matrix for Pass/Fail Scores on the Five Main Social-Cognitive Skills and Their Components for Children With Autism[a,b]

	Communicative gestures			Attention following			Imitative learning			Referential language
	Overall	Declarative	Imperative	Overall	Point	Gaze	Overall	Instrumental	Arbitrary	
Joint engagement	.29[c] (−)	−.11 (−)	.29 (−)	.00 (−)	−.10 (−)	−.26 (−)	.52[d] (−)	.52[d] (−)	.78[d] (−)	.52[d] (−)
Communicative gestures										
Overall	—	—	—	−.60 (.36[d])	−.71 (.33[e])	−.08 (.19)	.36[f] (.33[e])	.36 (.30[e])	.08 (.21)	−.26 (.06)
Declarative		—	.49[e] (.16)	−.41 (.36[d])	−.68 (.33[e])	.26 (.19)	.17 (.33[e])	.17 (.30[e])	−.26 (.21)	−.52 (.06)
Imperative			—	−.60 (.05)	−.71 (.12)	−.08 (.32[e])	.36 (.12)	.36 (.00)	.08 (−.09)	−.26 (.08)
Attention following										
Overall				—	—	—	−.21 (.27)	−.21 (.20)	.16 (.19)	.43[e] (.17)
Point					—	−.08 (.41[d])	−.26 (.19)	−.26 (.13)	.08 (.28)	.36 (.19)
Gaze						—	.14 (.41[d])	.14 (.30[e])	.20 (.42[d])	.14 (.33[e])
Imitative learning										
Overall							—	—	—	−.09 (.19)
Instrumental								—	.67[d] (.53[d])	−.09 (.21)
Arbitrary									—	.67[d] (.30[e])

[a] Correlations for 12-month-old, typically developing infants from Carpenter *et al.*, 1998, are given in parentheses.
[b] Spearman correlations with one-tailed p values were used. All typically developing infants had passed joint engagement by 12 months so this skill could not be correlated with the other skills.
[c] NS, but the correlation between joint engagement and imperative gestures was significant when imperative verbalizations with looks were added to imperative gestures, $r = .56$, $p < .05$.
[d] $p < .05$.
[e] $p < .09$.
[f] NS, but the correlation between imitative learning (and imitation of instrumental actions) and imperative gestures was significant when imperative verbalizations with looks were added to imperative gestures, $r = .52$, $p < .05$ for both.

and only one child showed the reverse pattern; two children passed both), the negative correlation between attention following and communicative gestures was based on a different pattern of individual responses. Five children passed attention following but not communicative gestures, and four children showed the reverse pattern (and three passed both).

Figure 4 presents a depiction of all the significant, positive correlations found for children with autism. Note the triangles of relatedness connecting (1) joint engagement, imitation of arbitrary actions, and referential language and (2) imitation of instrumental actions, imperative gestures, and joint engagement, as well as the many interrelations among joint engagement, referential language, spatial reversal, and object permanence.

In summary, for children with autism, there were many positive correlations between the social-cognitive skills—especially between joint engagement and referential language and the other skills. However, there were also some strong negative correlations between some skills, suggesting, again (i.e., along with the ordering results), an inconsistent ordering for these children.

Object-Related Skills

For children with autism, the addition of the two object-related skills to the pattern of the five main social-cognitive skills (object permanence fit at the beginning and spatial relations fit at the end) did not make much difference in the (lack of) scalability ($I = -.19$). For these children, there were prerequisite relations between object permanence and all the main social-cognitive skills (and also spatial relations), and there were prerequisite relations between referential language and spatial relations, and between attention following and spatial relations. There were a few sig-

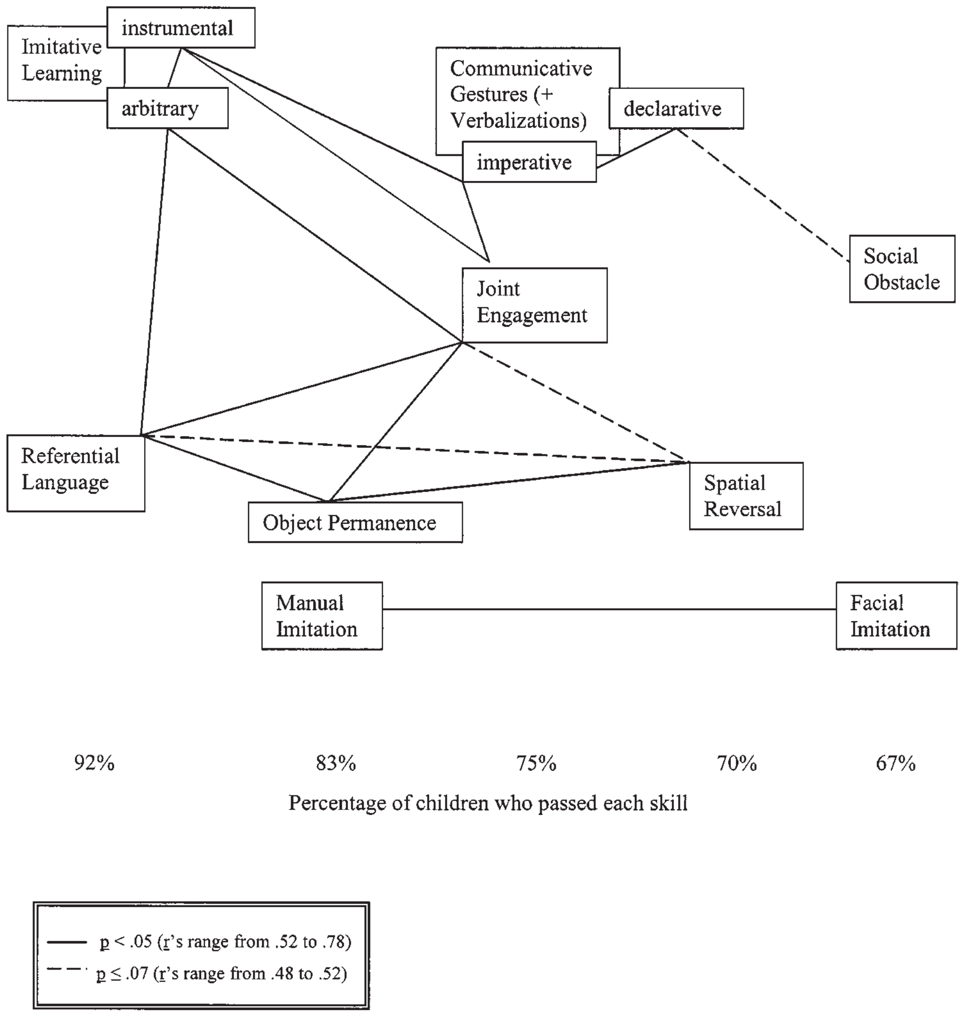

Fig. 4. All significant positive correlations for children with autism.
Note. We used Spearman correlations with one-tailed *p* values for correlations among the different social-cognitive skills and their component tasks (including social obstacle), and for correlations between spatial reversal and the different social-cognitive skills and their component tasks. Two-tailed *p* values were used for all other correlations. Because all children with autism passed the object permanence test used by Carpenter *et al.* (1998) as a criterion, we used the next most difficult test (one invisible displacement with two screens alternated) for correlations (83% of children with autism passed this test). Verbalizations with looks were included in communicative gestures in these analyses.

nificant correlations between object-related and social-cognitive skills for children with autism. Object permanence, in particular, was positively correlated with referential language and joint engagement (Fig. 4), and spatial relations was negatively correlated with imitation of instrumental actions and imperative gestures.[8]

[8] For typically developing infants, there were no significant correlations between object permanence and any other skill. There was a significant, positive correlation between spatial relations and imitative learning (and a marginally significant, positive correlation between spatial relations and gaze following).

Correlations With Chronological and Mental Ages

We also investigated correlations with chronological, verbal mental, and nonverbal mental ages. Very few significant correlations were found: attention following was marginally negatively correlated with chronological age ($r = -.54$, $p = .07$), both communicative gestures including verbalizations ($r = .42$, $p = .087$) and object permanence ($r = .67$, $p < .02$) were positively correlated with verbal mental age, and point following was positively correlated with nonverbal mental age ($r = .59$, $p < .05$).

DISCUSSION

Children with autism had more difficulty than did children with developmental delays with two of the three types of joint attention skills: gaze following and declarative gestures. Although 25% fewer children with autism than children with developmental delays initiated joint engagement, this was not a statistically significant difference. However, our measure of joint engagement was not a very sensitive one, as it required only one triadic look during an entire session of approximately 45 minutes. The tests that we used were originally designed for typically developing, 9- to 15-month-old infants, so, not surprisingly, there were ceiling effects on many tests, especially for children with developmental delays. The fact that joint attention deficits were still found even with ceiling effects indicates the robustness of these deficits.

Deficits in joint attention skills were also reflected in the ordering pattern of children with autism. Although most typically developing infants shared, followed, and directed others' attention before others' behavior, the skills involving others' attention were more difficult than those involving others' behavior for children with autism. The majority (67%) of children with autism showed the following pattern when skills were ordered by the number of children passing each one: follow behavior → share attention → direct behavior → follow attention → direct attention. These results suggest that developmentally, these children probably follow the typical pattern of sharing → following → directing within the areas of behavior and attention separately, but, atypically, for these children, the sequence involving behavior begins before the sequence involving attention. Thus, one main finding that emerged from this study is that although children with autism have robust joint attention deficits, when they do develop joint attention skills, they apparently do so in the typical order of sharing, then following, and then directing others' attention.

However, a second main finding of the current study is that at a more microlevel of analysis (i.e., at the level of the specific skills and their components as opposed to the level of the general functions of these skills in terms of sharing, following, and directing), the ordering patterns of individual children with autism are less consistent. As a group, children with autism passed the skills in the following order: imitative learning → referential language → joint engagement → attention following → communicative gestures. These group results did not translate to reliable individual patterns, however, as they did with typically developing infants, either for the sequence as a whole or, to a lesser extent, for individual pairs of skills.

Thus, with regard to ordering at the level of the main social-cognitive skills and their components, the picture for children with autism was, for the most part, not one of strong interrelations among skills. Some of the correlational results support this picture. There were some strong negative correlations for children with autism (unlike for typically developing infants). Attention following was negatively correlated with communicative gestures and, in particular, point following was negatively correlated with both declarative and imperative gestures. Again, these findings suggest that individual children with autism may follow different developmental routes with these skills; that is, some children comprehend others' gestures before producing gestures themselves, whereas other children produce gestures before comprehending others' gestures (see Carpenter *et al.*, 1998, for further discussion of this issue). One possible explanation of the individual differences revealed by both the ordering and correlational results is that children with autism may develop these skills in different ways than do other children, such as through training and reinforcement of individual skills, with different parents and therapists emphasizing different skills for intervention.

Still, many of the social-cognitive skills and their components were positively interrelated for these children, as they were for typically developing infants. Referential language and joint engagement in particular were positively related to most other skills in some way. However, any conclusions about interrelatedness of the social-cognitive skills must be tempered by the finding that object permanence was also strongly related to both referential language and joint engagement (and this was not the case for typically developing infants). Thus, the findings of the current study were mixed: we found many differences between children with autism and other children, but we also found some important similarities, the most important of which is, we believe, the suggestion that children with autism may follow the same share → follow → direct pattern as typically developing infants within the areas of attention and behavior separately.

Of course, there are many limitations to what we can conclude about developmental orders of emergence from this study. One set of limitations concerns the participants used in this study. First, the sample size was very small, and there were ceiling effects on some measures. Both of these factors probably reduced our chances of finding between-group differences. In addition, many of the children that we tested were working on the skills we tested in their intervention programs. We may have found more differences if we had tested children who had not yet participated in such programs (although those children would have been much more difficult to test).

There also are several methodological and interpretive limitations. The cross-sectional method used was not ideal for this type of study, because we had to work under the assumption that cross-sectional results reflect true developmental patterns. Although this is the assumption that underlies the ordering analyses that we used, and the assumption was confirmed in the Carpenter *et al.* (1998) study, it is possible that this assumption may not hold in atypical development. It is also possible that what we measured was not the presence or absence of these skills (i.e., whether or not they had emerged developmentally) but instead was the children's tendency or motivation to use the skills. It is likely that some children who did not pass a given skill could in fact engage in that skill but did not for some reason during the testing session. This would affect the ordering results, but it is of course a potential problem in longitudinal studies, too. On the other hand, it may appear that the children with autism in the current study were performing better than most other young children with autism on some measures (e.g., joint engagement), but it is important to keep in mind that we did not measure frequency of use of the skills in this study. Just because children showed one good instance of a skill in a 45-minute-long session does not mean that they used the skill with the same frequency or functionality as other children.

Other potential problems involve the tasks and materials used. It is possible that the ordering found in this and the original Carpenter *et al.* (1998) study was a function simply of the measures we used and did not have anything to do with children's social-cognitive understanding. For example, perhaps acting directly on nearby objects (as in our imitation tasks) is easier in terms of motoric skills or attentional demands for some children than is acting with respect to distant objects (as in our pointing measure; see Moore, 1998, for a similar argument). We doubt that this kind of explanation can completely explain our results, however, because declarative and imperative gestures require the same motoric skills, yet twice as many children with autism produced imperative as declarative gestures. Furthermore, our imitative learning tasks—like all the joint attention tasks—required a shifting of attention. Still, future studies in this area should use different tasks and should also use larger samples, longitudinal methods, and should administer tasks that can be scored more qualitatively instead of as pass/fail, to lessen the risk of ceiling (or floor) effects.

Despite this study's limitations, we believe that if our findings are supported by future longitudinal research with larger samples, they have some important theoretical and clinical implications. First, they address the issue of universality in the development of the social-cognitive skills we measured and the issue of deviance versus delay in autism. We found that for children with autism, the sequence of development of skills involving others' behavior and others' attention is likely different from that of other children—the joint attention skills are delayed—but the pattern of sharing, following, and directing within the domains of both attention and behavior is the same. Children with autism thus also apparently follow the typical developmental sequence of first understanding *that* others have psychological relations such as attention to the world before understanding *what* the content of those psychological relations is (see Carpenter *et al.*, 1998, for further discussion). The group of joint attention skills thus may have universal ordering (at least for human children; some nonhuman animals may show some of these skills but there are few studies of interrelations among them; see Carpenter, Tomasello, & Savage-Rumbaugh, 1995, for one such study of some correlational relations with chimpanzees and bonobos).

Second, our results also have implications for the universality of processes of language development across children. Although typically developing infants begin initiating joint attentional engagement episodes several months before uttering their first referential words (Carpenter *et al.*, 1998), this sequence may be reversed in children with autism. Our ordering results suggest that these children (both as a group and across individuals) may begin to produce referential words before engaging in nonlinguistic joint attention. Furthermore, children in this study were matched on verbal mental age yet children with autism showed robust joint attention deficits.

Anecdotal and experimental evidence (Baron-Cohen, Baldwin, & Crowson, 1997) suggests that children with autism do not use joint attention to learn new words to the same extent as do other children. Yet many of these children acquire extensive vocabularies. Our results support Rogers and Pennington's (1991) account of how they might do this without joint attention. Children with autism performed equally as well as children with other developmental delays on our imitative learning tests. Furthermore, imitative learning of arbitrary actions was positively correlated with referential language for children with autism (just as it was for typically developing infants; Carpenter *et al.*, 1998). We thus suspect that children with autism may be using something else—imitation—to enter into the process of language acquisition. Use of imitation without (or with little) joint attention would account for many of the atypical features of the language of children with autism, such as echolalia, "metaphorical speech," pronoun reversal, and use of questioning intonation for statements (Tager-Flusberg, 1993; see also Carpenter & Tomasello, 2000, for further discussion of these issues). Of course, if these children can and do use joint engagement and attention following, this can only be helpful for language acquisition (and that is why we and many others find correlations between these two skills and referential language). How words are learned and used by children with autism who are this young is an important topic for future research.

Finally, our results have some interesting clinical implications. If imitation leads the developmental line into joint attention and verbal and gestural intentional communication, this underscores the importance of developing imitation skills for children with autism. Imitation skills may represent an altered route to social knowledge, developing as a detour around the social-emotional barriers that autism creates. Language may play this role, too: once children with autism enter the world of speech, this may itself lead children into a greater awareness of others' psychological relations with the world, much as it appears to do in blind infants (Fraiberg, 1977; see also Tager-Flusberg, 2000).

In conclusion, we believe that this study is a useful first step in determining how various social-cognitive skills are interrelated in children with autism. We hope that it stimulates further research, and especially longitudinal studies, on developmental interrelations among these important skills. Another interesting future extension of these kinds of studies would be to explore interrelations between these skills—especially the joint attention skills—and the later-developing theory of mind skills, which are also almost universally impaired in individuals with autism.

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