Imitation and Pantomime in High-Functioning Adolescents with Autism Spectrum Disorders

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Imitation and Pantomime in High-Functioning Adolescents with Autism Spectrum Disorders. Child Development, 1996, 67, 2060-2073. A study was designed to test 2 alternative hypotheses—a symbolic hypothesis and an executive function hypothesis—for the imitation and pantomime deficits found in previous studies of autism. The subjects were 17 adolescent high-functioning subjects with autism spectrum disorders and 15 clinical comparison subjects who were matched on chronological age and verbal IQ. Meaning and sequence were manipulated in facial and manual imitation tasks. Sequence was manipulated in the pantomime and control tasks. Recognition memory and motor control tasks were matched to the experimental tasks. The results provided no support for the symbolic deficit hypothesis; meaning aided rather than hindered the performance of the group with autism. Partial support for the executive deficit hypothesis was found. There were no group differences on motor control tasks, and few on the memory control tasks, arguing against deficits in motor initiation, basic motor coordination, or visual recognition memory.

Autism is a severe disability involving impairments in social relatedness, language, behavior, and cognition. Because autism devastatingly affects behaviors that are so fundamental to social functioning, there is an active search for developmental models that can (1) account for the various symptoms, (2) guide the search for underlying neurobiological mechanisms, and (3) lead to more effective treatments.

In 1991, Rogers and Pennington suggested that a motor-imitation deficit might be a core deficit in autism. Using Stern’s (1985) model of interpersonal development, they hypothesized that a biological impairment in motor imitation could create a cascade effect, impeding early affective, social, and communicative development. They also postulated that imitation deficits in autism might result from underlying executive deficits. Working from a similar model, Meltzoff and Gopnik (1993) suggested that early imitation skills provide the infant with information about other persons that is crucial for developing a sense of “other minds,” and that a deficit in imitation might impede development of a theory of mind. In contrast, Baron-Cohen (1988) hypothesized that imitation deficits in autism are secondary to an underlying symbolic deficit related to the primary metarepresentational deficit. Consequently, testing whether the imitation deficits in autism are consistent with a sym-
bolic deficit versus an executive deficit provides one test of two competing theories about the nature of the primary cognitive deficit in autism: the metarepresentational theory versus the executive theory. That is the main goal of the current study.

In what follows, we will (1) review previous studies of imitation in autism, (2) elaborate the predictions made for imitation performance by the symbolic versus executive deficit hypotheses, and (3) describe the present study.

Studies of Imitation in Autism

The difficulty children with autism have in imitating another person’s actions was first described in the research literature by DeMyer and colleagues (DeMyer et al., 1972). A series of published studies of imitation skills of subjects with autism involving both higher- and lower-functioning subjects, ranging in age from preschool to adulthood, compared to matched clinical comparison subjects, have reported consistent findings of imitation deficits in subjects with autism (e.g., Bartak, Rutter, & Cox, 1975; Hammes & Langdell, 1981; Hertzig, Snow, & Sherman, 1989; Loveland et al., 1994; Ohta, 1987; Sigman & Ungerer, 1984; see Meltzoff & Copnik, 1993; Rogers & Pennington, 1991; and Smith & Bryson, 1994, for detailed reviews). In contrast, two studies of subjects with autism have not demonstrated imitation deficits, but both studies used infant measures. In one study, Bartak et al. (1975) compared imitation skills with older verbal subjects and were compromised by ceiling effects (Charman & Baron-Cohen, 1994; Sigman & Ungerer, 1984). Our study was designed to avoid these methodological problems and to permit a clear test of two alternative mechanisms, a symbolic deficit versus an executive deficit.

Predictions of the Symbolic versus Executive Deficit Hypotheses

Two current competing theories of the core or primary cognitive deficit in autism are the metarepresentational theory (Baron-Cohen, 1988; Leslie, 1987; Morton & Frith, 1994) and the executive or “frontal” theory (Damasio & Maurer, 1978; Hughes & Russell, 1993; Ozonoff, Pennington, & Rogers, 1991). Since each of these theories makes different predictions about the nature of the imitation deficit in autism, a test of those different predictions provides a validity test of each theory. Furthermore, as mentioned earlier, imitation deficits in autism are of considerable theoretical interest aside from those two theories, because in normal children imitation occurs very early and may be crucial for the normal development of other aspects of social cognition, including theory of mind.

In the metarepresentational theory, the postulated primary cognitive deficit is in a computational process called the “expression raiser” (EXPRAIS), which allows one to form second-order representations that are postulated to be necessary both for representing another person’s beliefs, desires, and intentions and for symbolic play (Baron-Cohen, 1988; Leslie, 1987; Morton & Frith, 1994). Perhaps the greatest challenge to the metarepresentational theory is the finding of deficits in autism in aspects of early social cognition that do not require metarepresentation. Joint attention is one example. Although the metarepresentational theory has been extended to account for joint attention (and other aspects of social cognition occurring in the first year of life—Morton & Frith, 1994), whether joint attention actually requires the computations performed by EXPRAIS is debatable (e.g., Mundy, Sigman, & Kasari, 1993). An even clearer example is imitation, since it is highly unlikely that imitation requires metarepresentation. However, imitation deficits found in older children with autism could be explained as secondary to the consequences of the primary deficit in EXPRAIS. One such explanation (Baron-Cohen, 1988) is that the difficulties that children with autism have on
imitation and pantomime tasks are secondary to underlying symbolic deficits related to the primary metarepresentational deficit in this disorder. The current study poses a validity test for the metarepresentational hypothesis by asking whether the imitation deficits found in autism are consistent with a symbolic deficit.

In the executive theory, the postulated primary cognitive deficit is in executive functions, which is a neuropsychological term for cognitive processes thought to be mediated by the prefrontal cortex. Although theorists have provided several different accounts of what those processes are, there is convergence across accounts that both working memory and inhibition are key cognitive processes in various executive tasks (Pennington, 1994). In the Rogers and Pennington (1991) paper, it is postulated that an underlying deficit in executive functions could cause an early deficit in imitation, leading to a cascade of other deficits in developing social cognition. An executive function deficit would affect imitation because imitation requires the formation of a body movement plan, which must be held on line in working memory while the plan is executed; correct execution requires inhibition of competing motor plans. Patients with acquired frontal lesions have deficits in a variety of motor sequencing tasks; a recent simulation of those deficits (Kimberg & Farab, 1993) found that weakening connections in working memory produced a deficit in motor sequencing because of a failure to inhibit competing motor plans. One corollary of this work is that longer sequences are more likely to lead to deficient performance.

These two different cognitive theories of autism predict different performance profiles by subjects with autism on imitation tasks. A symbolic deficit should lead to differential deficits in subjects with autism on meaningful as opposed to nonmeaningful imitation tasks. An executive deficit should lead to differential deficits on sequential tasks as opposed to nonsequential tasks. Obviously, these two possible explanations of an imitation deficit do not exhaust all the possibilities; we return to the issue of other possible mechanisms in the Discussion.

In addition, we are not postulating that meaning and sequence, which reflect working memory load, are completely independent in their effects on imitation performance. For subjects without disabilities, a meaningful sequence should impose less of a working memory load than a nonmeaningful one, and thus result in better performance.

The Present Study

The present study was designed to examine the performance of high-functioning adolescents with autism spectrum disorders on a variety of imitation and pantomime tasks in order to test these two alternative hypotheses. Specifically, we manipulated both meaning and sequence in both manual and facial imitation tasks; we manipulated sequence in the pantomime tasks. We included memory and motor control tasks to evaluate whether group differences were due to problems in those areas. The study addressed the following questions: (1) Are motor imitation and pantomime deficits present in high-functioning adolescents with autism spectrum disorders compared to clinical comparison subjects matched on chronological age (CA) and verbal IQ? If so, (2) Is the performance of subjects with autism differentially poorer on symbolic or meaningful tasks than on nonmeaningful tasks (consistent with a symbolic deficit); and/or (3) Is their performance differentially poorer on sequential tasks than on nonsequential tasks (consistent with an executive deficit)?

METHOD

Subjects

Two groups of subjects, aged 11 to 21, participated in the study. The first was a group of 17 high-functioning persons with autism spectrum disorders (hereafter referred to as autism) (mean CA = 15.5 years). They included 15 males and 2 females, 15 of European origin, 1 of African American origin, and 1 of Hispanic origin. Their diagnoses were Autistic Disorder (n = 9) or Pervasive Developmental Disorder Not Otherwise Specified (PDDNOS) (n = 8). Since the aim of this study was to see what deficits remained in high-functioning older subjects, the PDD subjects were retained in the autistic group, with the rationale that any bias they might introduce would be a conservative bias against finding the hypothesized differences.

The comparison group was matched with the autism group on CA and Verbal IQ and consisted of 15 subjects, 14 males and one female, with diagnoses of dyslexia (10), borderline IQ (2), ADHD (1), genetic disorder (1), and unspecified (1). All were
of European ancestry. All comparison subjects achieved CARS scores below 24, and were without autistic symptoms. A mixed-diagnosis comparison group was specifically chosen to control for the general effects of having some type of central nervous system dysfunction. No subject had any observable motor impairment.

All subjects obtained Full-Scale IQ score estimates above 69 on previous testing on the WISC-R (Wechsler, 1991). Bennetto et al. (1996) provide a detailed description of selection and matching procedures. As can be seen in Table 1, the two groups were similar in IQ, age, sex, SES (Hollingshead, 1975), and handedness.

Measures

Imitation and Pantomime Tasks

Three kinds of tasks were taken from the imitation and pantomime literature: hand imitations, face imitations, and pantomime tasks. The experimental and control tasks are listed in Table 2 and are available from the first author.

Hand tasks.—Four experimental conditions were generated by crossing the dimensions of meaning and sequence in a 2 x 2 within-subjects design. The four conditions were as follows.

1. Five single nonmeaningful movements (e.g., Extend arm and hand straight out in front of body, with fingers fanned out, and thumb pointed to ceiling; Kimura & Archibald, 1974).

   2. Six single, meaningful, familiar movements (e.g., Put arms over head, clasp together and shake. Examiner says, “Show someone that you are a champion”).

   3. Six sequential, nonmeaningful movements (e.g., With fingertips and thumb tip held together and placed on the same shoulder, move the hand out forward and horizontally from the shoulder, rotating and opening it widely as it moves and extends; Kimura & Archibald, 1974; Kolb & Milner, 1981).

   4. Six sequential, meaningful movements (e.g., Make a grasping motion with the right hand at mid forehead as if to remove a brimmed cap, then extend the arm to the right with the hand opening as it reaches the final fully extended position. Examiner says, “I’m going to take off my cap and put it in the laundry basket”).

We attempted to equate meaningful and nonmeaningful movements in difficulty. Movements were presented two times for each hand, and the subject was asked to imitate the movement after each presentation. Administration and scoring systems from Kolb and Milner (1981) and Kimura and Archibald (1974) were used. All tasks were videotaped and scored from the tapes.

For single movements, a correct imitation (involving spatial location, hand/arm posture, and movement pattern) was scored 2, a partially correct and recognizable imitation was scored 1, and a completely inaccurate movement was scored 0. There were

| TABLE 1 |
| Descriptive Characteristics of the Sample |

<table>
<thead>
<tr>
<th></th>
<th>Autistic Group (n = 17)</th>
<th>Comparison Group (n = 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD) (Range)</td>
<td>M (SD) (Range)</td>
</tr>
<tr>
<td>CA</td>
<td>15.50 (3.12) (11.00–23.00)</td>
<td>14.49 (2.97) (11.00–21.00)</td>
</tr>
<tr>
<td>VIQ</td>
<td>84.75 (14.72) (60–103)</td>
<td>93.60 (15.34) (68–122)</td>
</tr>
<tr>
<td>PIQ</td>
<td>96.19 (16.22) (68–125)</td>
<td>101.53 (17.43) (75–140)</td>
</tr>
<tr>
<td>FSIQ</td>
<td>89.38 (12.12) (72–109)</td>
<td>97.97 (16.62) (70–134)</td>
</tr>
<tr>
<td>CARS</td>
<td>34.25 (3.93) (30–42.5)</td>
<td>18.47 (3.07) (15–25)</td>
</tr>
<tr>
<td>SES</td>
<td>45.76 (9.62) (27–63.5)</td>
<td>46.14 (15.16) (13–66)</td>
</tr>
</tbody>
</table>

Note.—Sex (M:F): autistic group (15:2), comparison group (14:1). Handedness (R:L): autistic group (14:3), comparison group (14:1).
virtually no instances in which a subject produced no movement at all. Sequential hand movements were scored in four categories to capture the greater complexity of these movements: starting position, ending position, direction of movement, and accuracy of the postural changes, as described by Kolb and Milner (1981). Each of these categories was scored 2 for complete accuracy, 1 for an inaccuracy on one of the main criteria for that category, or 0 for errors in two or more criteria for that category. Thus, when totaled, scores for each hand sequence could range from 0 to 8. Scores from each set of experimental movements were summed and converted to percent correct scores so that all scores were on the same metric.

Scores from the first presentation for each dominant hand were used for all hand movements throughout the study. Preliminary analyses using t tests demonstrated significantly better performance within subjects with the dominant hand on only one hand task, meaningful single hand movements ($t = -7.11, p < .001$). Hence, similar overall results would have been found had nondominant or combined hand scores been used. Furthermore, there was no group × hand interaction for any of the hand tasks.

### Facial Tasks

Again, four experimental conditions were generated by crossing the dimensions of meaning and sequence in a within-subjects 2 × 2 design. The nonmeaningful facial imitations were adopted from the work of Kolb and Milner (1981; based on work by Mateer & Kimura, 1977). The meaningful facial imitations were modeled after work reported by Hertzig et al. (1989). The four dimensions involved:

1. **Twelve single nonmeaningful movements** (e.g., tongue protrusion with mouth open).
2. **Five three-movement sequences consisting of movements from the single nonmeaningful series.**
3. **Six single, meaningful, facial expressions** (happy, sad, frightened, angry, surprise, disgust).
4. **Four three-movement sequences consisting of meaningful expressions from the single series.**

For all meaningful tasks, the expression was verbally labeled (i.e., “This is how I look when I feel really angry at somebody. Make your face look really angry, just like mine.”). The experimenter modeled facial expressions from Izard’s (1971) classic emotion expression faces (happy, surprised, scared, angry, sad, disgust). Similarly, with the meaningful sequences, each expression was labeled verbally as it was being demonstrated in the series.

All facial movements were presented twice. On the single-movement tasks, if the movement had not been made perfectly, a third trial (described below) was given as a motor control. It was not necessary to administer the motor control on the sequential series since they were made up of movements from the single series. A memory control trial followed each of the two sequential tasks as described below. Scores from the first trial were summed across all the items.
in a set. For single movements, a perfect imitation was scored 2, a partially correct and recognizable imitation was scored 1, and an unrecognizable movement was scored 0. For the sequential movements, the subject received 1 point for each movement correctly performed in the correct position in the sequence (or performed similarly to the best performance in the motor control trial; thus, this score reflects sequential performance more than accuracy of imitations). For all scores a percent correct score was calculated.

Motor and Memory Control Tasks

A third trial was given after each set of hand and face imitation tasks as a motor control task. In the third trial, the experimenter asked the subject to produce the movement as the experimenter was modeling it. All errors in the subject's movement were corrected immediately through verbal and physical feedback. The corrected movement was scored pass or fail depending on whether the subject could physically perform the movement when the errors were corrected. Thus, the third trial functioned as a motor control task to assure that the subjects could actually make the necessary movements when all their errors were physically and verbally corrected. It differed from the imitation trials in that it was both immediate and assisted by considerable prompting; it was not an immediate or simultaneous imitation task.

After each set of hand and face tasks, the recognition memory trial was administered. Recognition memory control tasks consisting of sets of photos of the actual experimental movements were used for most imitation tasks to test for possible effects of short-term memory problems (Kimura & Archibald, 1974). The single hand movement memory control tasks consisted of a set of photos of the target movement and five distractors. The sequential hand and face movement memory control tasks consisted of the target sequence and two distractors. The sequential face memory tasks also served as memory controls for the single face tasks since the same movements were used for both tasks. After each set of imitation tasks was administered, the experimenter informed the subject of the nature of the memory control task, modeled one of the movements (or sequence of movements), then showed the subject a set of photos and asked the subject to point to the picture of the movement (or series of movements) just modeled. Each memory control item was scored pass or fail.

Pantomime Tasks

Pantomime skills were included in this imitation study because they, along with motor imitation, are considered classic tests of praxis, and because earlier autism studies demonstrated pantomime deficits (Bartak et al., 1975). The pantomime experiment consisted of a within-subjects manipulation of sequence, resulting in two experimental conditions. The single pantomime tasks were taken from DeRenzi and Luchelli (1988). The sequential tasks were developed for the purposes of this study.

The pantomime battery consisted of (1) 20 single pantomimed meaningful familiar movements involving the use of common objects (e.g., toothbrush, scissors); (2) five sequential meaningful pantomimed movements involving the use of common objects; and two control tasks, involving (3) 10 imitation tasks in which the subject imitated the experimenter using the real object in the appropriate way; and (4) 10 tasks in which the subject demonstrated the real use of the object without any model.

For both experimental tasks, a real object was placed on the table for the subject to name (to ensure that the subject knew the object) and kept in view on the table but not available for manipulation during the trial. For each object, the subject was asked, "What is this? Show me how you use it." Twenty objects were used and each task was given twice. A demonstration trial was given first, and the subject was coached and prompted on this task to make sure he or she understood the task. If the subject began to use the hand as if it were the tool, the examiner prompted, "Pretend you are holding the [object]."

Performance was scored 4 for an accurate and elaborated movement (almost no one elaborated any movements), 3 for a completely accurate movement, 2 for a clearly recognizable but not perfect movement, 1 for a very imprecise but recognizable movement, and 0 for a nonrecognizable movement. The two control tasks were scored 2 points for an accurate movement, 1 point for an inaccurate but recognizable movement, and 0 for an unrecognizable movement. Scores from the first trial of each item were summed across all items and a percent correct score was calculated. The highest score achieved by any subject was used (62) as the total score in order to calculate percentages.

The same procedures were used for sequential pantomimes with the additional in-
struction that they were to demonstrate all the movements involved. The first item was again a demonstration; subjects were prompted to make sure that they understood that a series of movements was required. Then five experimental trials were given (a cup and pitcher, paper and envelope, lock and key, toothbrush, and iron). For each object, subjects were asked, “What is this? Show me all the movements you would make while using this.” Subjects were given 1 point for each separate movement in the sequence, summed across the five tasks.

Procedures

A consistent order of tasks was used for all subjects in each testing session. This order was used so that the subjects began with the easiest hand movements, in order to learn the test protocol. Face movements were given after the subjects were “warmed up” to decrease self-consciousness.

Raters were initially trained to reliability; thereafter reliability was spot-checked across 16% of the protocols. Raters were blind to group membership of the subjects. On rater disagreements of more than 1 point, consensus scores were agreed upon and assigned. Interrater reliability was calculated using intraclass correlations and ranged from .80 to .99, with a mean correlation of .93. Intraclass correlations were used rather than kappa because of the continuous nature of the scores (Mitchell, 1979), as well as to avoid the possibility of falsely high Pearson correlations that might be obtained if there were systematic, consistent differences between scoring pairs.

The tasks were given in two 1–1½ hour sessions. The first session consisted of several measures not being reported here, a break, and then imitation and pantomime tasks: meaningful single hand, nonmeaningful sequential hand, meaningful and nonmeaningful single face, nonmeaningful sequential face, and most of the pantomime tasks, followed by two brief tasks not being reported here.

The second session involved several measures not being reported here, Wechsler Vocabulary and Block Design, and then nonmeaningful single hand, meaningful sequential hand, meaningful sequential face imitations, and sequential mime tasks. These two sessions were separated in time by several months.

Subject motivation was enhanced through use of substantial monetary reward ($25 per visit); use of experienced subjects; use of friendly, warm, interactive experimenters; and ample praise and encouragement. Subjective impressions from both experimenters and raters were that the subjects with autism were well motivated, worked hard at the tasks, found them enjoyable, and were not self-conscious about the hidden video camera. In contrast, an occasional comparison subject expressed self-consciousness or dislike of the tasks. If these motivational differences caused any bias, it would be a conservative one.

Results

Preliminary Analyses

The data were first reviewed for skew, kurtosis, and outliers. Except on the control tasks, there were no problems with floor or ceiling effects. When there was lack of a normal distribution (as on some control tasks), nonparametric statistical tests were used. Performance data on individual measures are presented in Table 3.

Main Analyses

In what follows, we present the results of the hand, face, and pantomime experiments. For the hand and face experiments, the order of presentation is (1) memory control tasks, (2) imitation tasks, and (3) motor control tasks.

Hand Tasks

Memory control tasks.—Group performances on the hand memory control tasks were compared using t tests (or Mann-Whitney U tests when appropriate). There were no significant differences between the groups on any of these four control tasks. The subjects with autism passed 100% of the two single-movement memory tasks, 94% of the nonmeaningful sequential memory tasks, and 96% of the meaningful sequential memory tasks. The comparison group passed 100% of all tasks except the nonmeaningful sequential memory tasks, on which they passed 99%.

Imitation tasks.—A mixed-model analysis of covariance (ANCOVA) with full-scale IQ (FSIQ) covaried with one within-subject factor (group) and two within-subject factors (sequence, meaning) was performed on the hand tasks. The ANCOVA revealed a three-way, group x sequence x meaning interaction effect, $F(1, 26) = 7.69, p = .01$. Post hoc tests of simple effects revealed significant group differences on three of the four hand tasks: the single nonmeaningful task, $t(26) = -2.88, p = .008$, the se-
| TABLE 3
| PERFORMANCE DATA AND GROUP DIFFERENCES ON BOTH INDIVIDUAL MEASURES AND COMPOSITES USING PERCENT SCORES |

<table>
<thead>
<tr>
<th>TASK (n)</th>
<th>AUTISTIC GROUP</th>
<th>COMPARISON GROUP</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td></td>
</tr>
<tr>
<td>Imitation tasks—hand:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonmeaningful single hand (28)</td>
<td>68.75 (16.28)</td>
<td>85.00 (12.43)</td>
<td>.008</td>
</tr>
<tr>
<td>Nonmeaningful sequential hand (32)</td>
<td>67.52 (19.11)</td>
<td>86.96 (6.83)</td>
<td>.001</td>
</tr>
<tr>
<td>Meaningful single hand (32)</td>
<td>75.88 (12.10)</td>
<td>77.67 (10.34)</td>
<td>N.S.</td>
</tr>
<tr>
<td>Meaningful sequential hand (28)</td>
<td>63.07 (18.48)</td>
<td>89.96 (8.08)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Imitation tasks—face:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonmeaningful single face (29)</td>
<td>83.79 (11.03)</td>
<td>88.13 (8.13)</td>
<td>N.S.</td>
</tr>
<tr>
<td>Nonmeaningful sequential face (29)</td>
<td>62.36 (15.46)</td>
<td>80.67 (18.33)</td>
<td>.007</td>
</tr>
<tr>
<td>Meaningful single face (29)</td>
<td>61.29 (10.70)</td>
<td>67.27 (15.80)</td>
<td>N.S.</td>
</tr>
<tr>
<td>Meaningful sequential face (24)</td>
<td>79.64 (14.17)</td>
<td>86.62 (13.06)</td>
<td>N.S.</td>
</tr>
<tr>
<td>Mime tasks:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single (32)</td>
<td>68.82 (18.16)</td>
<td>93.27 (7.61)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Sequential (28)</td>
<td>32.27 (19.44)</td>
<td>74.13 (17.07)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Object imitation (32)</td>
<td>95.88 (7.95)</td>
<td>97.00 (7.27)</td>
<td>N.S.</td>
</tr>
<tr>
<td>Object use (32)</td>
<td>96.19 (6.50)</td>
<td>98.33 (2.44)</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

Sequential nonmeaningful task, \( t(20) = -3.92 \), \( p = .001 \), and the sequential meaningful task, \( t(22) = -5.39 \), \( p < .001 \). As can be seen in Figure 1, the three-way interaction results from the fact that the hypothesized group \( \times \) sequence interaction was found across the two meaningful conditions but was essentially absent across the two nonmeaningful ones. These results provide partial support for the executive deficit hypothesis. In contrast, there was no group \( \times \) meaning interaction, thus providing no support for the symbolic deficit hypothesis; indeed, meaning clearly aided rather than hindered the performance of the group with autism on single movements.

![Figure 1](https://example.com/figure1.png)

**Fig. 1.**—Group differences on sequence and meaning scores for hand tasks.
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**Motor control tasks.**—The performance of the two groups was compared on the third, motor control trial in which subjects were given verbal and physical prompting as needed to correct their errors. It is important to note that the subjects' performance on this trial appeared to be as impaired as their performance on the experimental trials until the experimenter corrected their errors. Groups were compared by converting all the scores to percent correct and using Mann-Whitney \(U\) Tests to compare the means. There were no group differences on any of the four tasks. The autistic group performed at 100% correct on three of four conditions and at 95% correct on the meaningful, sequential condition. The comparison subjects also performed perfectly on three of four conditions and at 98% on the nonmeaningful single condition. Thus, there did not appear to be a general motor impairment that interfered with the ability of subjects with autism to make the constituent hand movements in these tasks.

Face Tasks

**Memory control tasks.**—Memory for faces was examined by recognition trials of the two face sequence tasks, and was analyzed using nonparametric Mann-Whitney \(U\) tests because of insufficient variance in the comparison group, who were at ceiling (100% correct) on both tasks. In comparison, the autistic group performed significantly worse. The autistic group was correct on 86% of the nonmeaningful sequential faces \((p = .01)\) and 89% of the meaningful sequential faces \((p = .01)\). Three subjects with autism passed 50% or fewer of these memory control tasks. Significant memory impairments thus could not be ruled out for these three subjects, and they were dropped from all further analyses of the face tasks.

On the memory controls for nonmeaningful face sequences, six of the remaining subjects with autism passed three of the four tasks, and eight passed all four tasks. In order to look for possible memory effects for the six subjects who did not score 100% on the memory tasks, the total scores of these six subjects on each of the face tasks were compared to the remaining subjects with autism. There were no significant differences on total scores for any of the experimental face tasks between the group of subjects with autism who passed 100% of the memory tasks and the group who passed 75%. Thus, we felt that memory problems were not interfering with performance on the face tasks for these subjects, and all of these subjects were included in the rest of the face analyses.

**Imitation tasks.**—A mixed-model ANCOVA with FSIQ covaried with one-between-subjects factor (group) and two within-subjects factors (sequence, meaning) was performed on the face tasks.

There was a main effect of group, \(F(1, 21) = 4.53, p = .04\), and a two-way meaning \(\times\) sequence interaction, \(F(1, 22) = 62.37, p < .001\). As can be seen in Table 3, on the two single facial tasks, both groups were more accurate on the nonmeaningful task than on the meaningful one; however, on the two sequential facial tasks, an opposite pattern was observed. The single meaningful facial task (imitation of six facial emotional expressions) involves coordinated movements of several different muscle groups. This task was much harder for both groups of subjects than the single nonmeaningful face movements, which were simple movements like open mouth, or tongue to side. The opposite pattern observed for sequential facial movements probably is due to the fact that (1) the scoring system did not emphasize accuracy of imitations on the sequential facial movements, and (2) the possibility that the verbal labeling of emotions helped all subjects retain the sequence in working memory.

Post hoc tests between groups revealed a significant group difference for the nonmeaningful sequential task only, \(t(27) = -2.90, p = .007\). The main effect of group revealed that subjects with autism performed more poorly than comparison subjects overall on the face imitation tasks. However, their most deficient performance occurred on nonmeaningful sequences. Again, these findings provided no support for the symbolic deficit hypothesis; indeed, once again, meaning clearly aided rather than hindered the performance of the group with autism relative to controls in the sequential condition. Furthermore, there is only partial support for the executive function hypothesis in that the subjects with autism were deficient on only one of the two sequential tasks.

**Motor control tasks.**—There were no significant group differences on the motor control trials for nonmeaningful single facial expressions or meaningful single face movements. Thus, there did not appear to be a general motor impairment that interfered with the ability of subjects with autism to
make these face movements compared to comparison subjects.

Pantomime Tasks
As can be seen in Table 3, both groups were at ceiling on the two object-control tasks, limiting our ability to test for group differences. For that reason, a mixed-model ANCOVA with FSIQ covaried was carried out with one between-subjects factor (group) and one within-subjects factor (sequence) on the pantomime tasks. The hypothesized group × sequence interaction was found, $F(1, 26) = 5.81, p = .02$, supporting the executive deficit hypothesis. Post hoc tests revealed significant group differences for both experimental tasks: single mime, $t(22) = -5.07, p < .001$; sequential mime, $t(26) = -6.01, p < .001$. The interaction results from a larger autistic group deficit on the sequential task (56% below the control mean) than on the single task (26% below the control mean). The pantomime task does not directly address the symbolic hypothesis because symbolic content was not manipulated.

Thus, subjects with autism did not differ in their ability to make normal motor movements using common objects, either on imitation or command, but they differed greatly from comparison subjects in their ability to pantomime the same movements, even with familiar objects present on the table.

Relationships among the Imitation and Mime Tasks
In order to examine relationships across the hand imitation, face imitation, and pantomime tasks, we correlated the three via composite scores that were constructed by computing the mean of the task scores. For both groups, the imitation and mime composites demonstrated some significant relationships with each other, with similar patterns seen in both groups. Hand and face task correlations were $.72 (p < .01)$ for controls and $.64 (p < .05)$ for the group with autism. Hand and mime correlations were $.41$ (N.S.) and $.52 (p < .01)$, respectively. Face and mime correlations were $.49$ and $.46$ (both N.S.), respectively.

Universality of the Imitation and Mime Deficit
In order to examine the question of the pervasiveness of the imitation and mime deficits in the autistic group, the number and proportion of subjects with autism scoring below the comparison group mean were examined for each of the experimental tasks on which there were significant group differences. The results can be seen in Table 4.

The six tasks on which there were significant group differences revealed universally poor performance of the subjects with autism. Thus, the group differences were not due to the very poor performance of a few subjects with autism, but rather reflect poor performance across a majority of the subjects in this group.

DISCUSSION

Presence of Imitation and Pantomime Deficits
The first question addressed in this study concerned the presence of imitation and pantomime deficits in high-functioning adolescents with autism. We found the group with autism to have deficits on one or more of the conditions in each of our three experimental tasks (hand, face, and pantomime). Thus, this study provides additional support for Rogers and Pennington's (1991) hypothesis that a specific deficit in motor imitation exists in persons with autism. It also adds to previous findings of pantomime deficits in autism. In what follows, we will first discuss why these imitation and pantomime deficits are not due to deficits in visual recognition memory, the ability to make the constituent movements, or the initiation of

### TABLE 4

<table>
<thead>
<tr>
<th>Task</th>
<th>Proportion</th>
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<tbody>
<tr>
<td>Sequential mime</td>
<td>13/13 (100%)</td>
</tr>
<tr>
<td>Single mime</td>
<td>16/17 (94%)</td>
</tr>
<tr>
<td>Nonmeaningful sequential hand</td>
<td>16/17 (94%)</td>
</tr>
<tr>
<td>Nonmeaningful sequential face</td>
<td>13/14 (93%)</td>
</tr>
<tr>
<td>Meaningful sequential hand</td>
<td>13/15 (87%)</td>
</tr>
<tr>
<td>Nonmeaningful single hand</td>
<td>13/15 (87%)</td>
</tr>
</tbody>
</table>
movements. Then we will discuss how the results bear on the two main hypotheses tested in this study: the symbolic and executive deficit hypotheses.

In terms of visual recognition memory, we attempted to control for possible memory confounds by using recognition memory tasks based on the experimental tasks. However, it is important to note that the memory control tasks tapped recognition memory, while the experimental tasks tapped recall memory. On the hand tasks, there were no group differences on the memory control tasks, while there were group differences on three out of four of the experimental tasks. So it is quite unlikely that the deficits in the imitation of hand movements are due to a deficit in visual recognition memory. Apparently the subjects with autism can visually encode the hand movements made by the model and remember them well enough to pass a recognition test. For facial movements, the situation is somewhat less clear. There were significant group differences on the facial memory control task, but these cannot account for the one significant group difference (in the sequential, nonmeaningful condition) because subjects with autism who scored perfectly on the memory control task were just as impaired on this condition as those who did not score perfectly. Perhaps most telling is the fact that the pantomime tasks do not require short-term visual memory because there is no model in the task to imitate. Yet subjects with autism were also impaired on the pantomime tasks. Thus, we can exclude a deficit in visual recognition memory, but the possibility that visual recall memory deficits affected the results has not been ruled out (it can be argued that even the pantomime tasks require long-term visual recall memory).

The possibility of a motor problem underlying the deficient imitation and pantomime performance of the subjects with autism was a second important factor that this study tried to control. Most strikingly, the subjects with autism demonstrated equivalent performances to the controls on the motor control tasks (with real objects in their hands), but could not perform comparably on the pantomime tasks (with no real objects in their hands). Thus, we can clearly reject a motor problem as an explanation for the pantomime results. On the hand and face motor control tasks, all subjects could make the constituent motor movements involved in each task, given sufficient prompting. While the motor control tasks took away a delay between the model and the performance, they did not reflect intact immediate imitation skills because the subjects with autism still required specific corrections and prompting in order to perform the movements accurately. Thus, it seems very unlikely that these subjects had intact ability to imitate movements when no delay is involved. Since we did not directly test motor function (apart from the motor control tasks), motor dysfunction in autism cannot be ruled out from these findings. However, the results from the motor control tasks argue against the group differences being only due to differences in basic motor functions.

Nor do the differences seem to be attributable to problems in initiating a movement sequence. All subjects attempted a movement on virtually every trial. Moreover, even the motor control trials required some motor initiation; since all subjects performed some movement in virtually every trial, inability to initiate these movements on request was not seen.

The Role of Meaning

The second question addressed by this study was whether imitation deficits in autism are consistent with a symbolic deficit, as postulated by the metarepresentational theory (Baron-Cohen, 1988).

The results of this study clearly reject the symbolic deficit hypothesis. Subjects with autism never performed differentially worse on the meaningful conditions. In fact, of the four significant group differences found on the hand and face tasks, only one was found on a meaningful task and three were found on nonmeaningful ones. Thus, there was no evidence from this study that suggested that these subjects with autism had particular difficulty imitating movements with symbolic content as opposed to nonsymbolic content. Deficits in nonmeaningful imitation are difficult for the metarepresentational theory of autism to explain; while imitation does require some mental representation of the target movement, it does not require a metarepresentation.

The Role of Executive Function

The third question driving this study was whether imitation deficits in autism are consistent with an executive deficit. There was partial support for this hypothesis. The predicted group × sequence interaction effect was found (1) across the meaningful conditions of the hand experiment, but not across the nonmeaningful ones, resulting in
a group × sequence × meaning interaction; (2) in the pantomime experiment; but (3) not in the face experiment. Moreover, there were significant group differences on two nonsequential tasks: the nonmeaningful single hand condition and the single pantomime condition. One could argue post hoc that even the single movements on which there were group differences exceeded the working memory capacities of these subjects with autism; however, testing that hypothesis will require an experiment in which working memory requirements are manipulated within nonsequential imitation tasks.

Overall, the performance of subjects with autism reflected rather widespread deficits in imitation and pantomime. Imitation and pantomime tasks are considered classic tests of praxis. Dyspraxia refers to a deficit in the capacity for consciously formulating and then executing an intentional motor plan in a particular context, a capacity not necessary for conditioned, automatic, or reflexive movement patterns (Ayres, 1985; Heilman, 1979). Deficits involving both face and hand imitations and pantomime are commonly found in apraxic neurologically impaired adults (DeRenzzi, Motti, & Nichelli, 1980; Kimura & Archibald, 1974; Kolb & Milner, 1981; Mateer & Kimura, 1977). Indeed, the tasks used in this study are considered classic tests of praxis. Given the generalized deficits across the majority of these tasks shown by the subjects with autism, it is important to raise the question of a generalized dyspraxia in autism.

Several previous autism researchers (DeMyer, Hingtgen, & Jackson, 1981; Jones & Prior, 1985; Ohta, 1987), presented with similar findings, have suggested that a dyspraxic deficit in autism is present and may interfere with even the simple motor activities involved in everyday life and normal nonverbal communication. A praxis hypothesis is not independent of an executive function hypothesis: executive function is involved in the execution of volitional movements, and persons with frontal lobe damage (which is generally associated with executive function deficits) demonstrate apraxia (Kolb & Milner, 1981). The question raised here is whether some other component of praxis besides executive functions is implicated in the praxis deficits in autism. We have ruled out visual recognition memory, simple motor deficits, and motor initiation. We have not ruled out visual recall memory, but, if we had ruled out a visual recall memory deficit, we would have in effect ruled out an executive deficit for the following reason. Visual recall memory in the context of imitation and pantomime tasks is not clearly distinguishable from the working memory and execution components of these tasks, which were discussed earlier. Recall memory requires production of something in memory, in this case, a remembered action. On these tasks, production of a remembered action required holding the representation of the action in working memory while executing the action. Thus, it seems unparsimonious to postulate separate constructs of recall memory and working memory in the context of imitation and pantomime tasks.

We cannot totally exclude the possibility that a low-level motor impairment makes complex motor tasks such as these differentially difficult. We cannot exclude the cross-modal match between model and self required in imitation tasks (Meltzoff & Gopnik, 1993), although the lack of group differences in several of our experimental conditions argues against a complete absence of the ability to form such cross-modal correspondences. Thus, more research is needed to specify the mechanism underlying the imitation and pantomime deficit in autism.

**Issues Involving Pantomime**

Findings involving the pantomime tasks raise several issues. One involves the co-occurrence of imitation and pantomime deficits. Pantomime can be thought of as a deferred imitation task, in which a subject must retrieve from long-term memory a representation of past behavior, then hold that representation on line in order to imitate it. Thus, the two kinds of tasks in this study can be conceptualized as immediate imitation and deferred imitation tasks, involving similar processes of working memory, motor planning, and execution, but differing as to which memory systems are most involved. This may explain the similar kinds of deficits found in pantomime and imitation performances in subjects with autism.

Another question that emerges is why the subjects with autism did not demonstrate difficulties on the pantomime control tasks, which required very similar movements. The movements associated with the object imitation tasks were simple, common, and probably well practiced by the subjects. It may be that having a familiar object in hand elicits an automatic motor scheme, akin to what Lhermitte (1983) has described as "utilization" behavior in frontal patients. This
result may implicate somewhat separate motor control systems, for instance, the basal ganglia for automatic motor schemes and the prefrontal cortex for intentional motor schemes.

A third issue is whether pantomime deficits are the result of a symbolic deficit (O'Reilly, 1995). If we found deficits only on the pantomime tasks, this would be a plausible explanation. But having rejected this hypothesis for the imitation tasks, and having found some relations between those tasks and the pantomime tasks, this possibility seems quite unlikely. In fact, the similarity between pantomime tasks and symbolic play point to an important weakness in the explanation of the symbolic play deficits in autism provided by the metarepresentational theory. When a child represents an object in play that is not present, the child is pantomiming a movement with a substitute object or an imaginary object. In the pantomime condition in this study, we are in fact asking subjects to pretend that they are ironing, drumming, etc. Our findings of deficits in imitation of actions that do not involve representation of objects, but only require representation of body movements, suggest that the symbolic play deficit in autism may have more to do with the representation of body movements in general than with actions specifically focused on symbolized objects, contrary to the metarepresentational hypothesis.

Methodological Concerns with This Study

One important potential threat to the validity of these findings concerns our group of subjects with autism. This group, as stated previously, has been the subject of several different investigations (Bennetto et al., 1996; Ozonoff & McEvoy, 1994). As often happens with a low-incidence disorder, the same subject group is returned to when new questions arise. However, the more tests that are run on a given group, the greater the risk of Type I error. Since it is not possible for most laboratories to recruit independent samples like the present sample for each study, it is extremely important that these findings be replicated in an independent group. The fact that most studies of imitation and pantomime in subjects with autism have resulted in findings similar to these, however, provides converging support for our conclusions that these findings point to a general imitation and pantomime impairment in autism.

Second, the use of a mixed clinical group of comparison subjects has drawbacks. Our rationale involved an effort to provide some control for the presence of a general central nervous system dysfunction. However, it can certainly be argued that different diagnostic groups have differential damage to specific brain systems that account for both symptoms and specific task performance characteristics. Thus, more may be learned from a neuropsychological standpoint by using homogeneous control groups.

Finally, the scoring system that was used on the face sequence tasks may well have masked group differences by emphasizing sequential accuracy over imitative accuracy. Future research will need to examine accuracy of imitation of facial sequences more closely.

References


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