Imitation in Children with Autism Spectrum Disorders: An Analysis of Task Type and Common Errors

by

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A thesis submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the Degree of
Master of Science

Auburn, Alabama
December 13, 2010

Keywords: autism, imitation, error analysis, multilevel modeling

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Abstract

The purpose of this study was to identify common imitative errors emitted by children with Autism Spectrum Disorders (ASD) and typically developing children across varying types of imitative tasks. Twenty-two low-functioning children with ASD, 9 high functioning children with ASD, and 18 typically developing children were included in this sample. Participants completed a series of 15 imitation tasks including object imitation, object-facial imitation, and facial imitation tasks. The prevalence of six error types (i.e., the need for multiple attempts, spatial errors, failure to attend, mirroring, non-compliance, and no-response) were assessed across these three types of imitative tasks. Additionally, accuracy scores were coded in order to examine differences in overall performance between both groups of children. The results of a multilevel model analysis revealed differences in the frequency of errors emitted across the three participant groups. Generally, the rate of errors increased as level of functioning decreased; nevertheless, children with high-functioning ASD emitted significantly more errors than typically developing children. Additionally, the pattern of errors emitted varied by task type for participants with ASD; however, task type appeared to have a more limited effect on the number of errors emitted by typically developing children. The implication of these results in light of several theoretical accounts of the "imitation deficit" in children with ASD is discussed.

Acknowledgments

I am grateful to Jennifer Gillis, Richard Mattson, and my committee members for their assistance in the completion of this project. I would also like to thank Lesa Hoffman for sharing her invaluable expertise in multilevel modeling.

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Introduction

Although imitation is suggested to be an innate and effortless ability, children with autism spectrum disorders (ASD) are often severely impaired in this capacity (for a review see Rogers & Williams, 2006; Williams, Whiten, & Singh, 2004). Despite the vast amount of evidence that exists in support of an "imitation deficit," the exact nature and extent of imitative difficulties in children with ASD is unclear. Indeed, several research findings have suggested that under certain conditions, children with ASD are capable of imitation (Ingersoll, 2008; Ingersoll, Schreibman, Tran, 2008; Hobson & Lee, 1999; Want & Harris, 1998). Thus, current research in this field has focused on differentiating the types of imitative tasks that inhibit or enhance imitative performance in children with ASD. The identification of tasks that present problems for this population can serve to increase knowledge of the "imitation deficit," inform theoretical accounts of imitation in children with ASD, increase current understanding of ASD more generally, and allow for tailoring treatments to the needs of children with ASD. Thus, it is increasingly important to identify the variables that improve and hinder imitative performance in this population.

Unfortunately, the construct of imitation is loosely defined within the ASD literature. The absence of a consistent definition of imitation, as well as different theories available to account for imitation in ASD, have led to several different types of imitative tasks. Tasks often vary significantly from one researcher to another, which often leads to differences in findings across researchers. However, differential performance across task types may serve to inform theories surrounding imitative deficits in children with ASD. For example, theories accounting for discrepant performance across tasks (e.g., motivational theories) may be favored over theories that conform to this finding less easily (e.g., deficient mirror neuron system). Furthermore, a comparison of the relationship between task type and imitative performance in children with ASD and children without ASD may further serve to elucidate what types of imitative targets should be selected for intervention.

In addition to a recent focus on the type of imitative tasks, researchers are beginning to identify prevalent error types emitted by children with ASD during imitation. The identification of error types has allowed for a more fine-grained analysis of imitative ability. Furthermore, the detection of errors in children with ASD and typically developing children has generated a more comprehensive understanding of the differences and similarities in imitative repertoires between these two groups. Rather than simply describing children with ASD as performing more poorly than typically developing children, researchers are becoming more able to explain the conditions under which these differences exist and what types of behaviors (e.g., failing to attend) may have caused children with ASD to fail imitation tasks.

Despite the vast amount of research related to imitation in children with ASD, differences in imitation across task types and types of imitative errors produced have yet to be assessed. That is, studies generally do not assess differences in errors across certain task types. The present study conducts such an analysis, as this relationship may serve to explain differences in performance across tasks and provide a more precise analysis of differences observed across task types (i.e., the difference in the number of errors across tasks). Additionally, a better understanding of the relationship between errors and task types may serve to inform theoretical accounts of imitation in children with ASD, as many error types are linked to theoretical explanations of the "imitation deficit."

The Effect of Task Type

The first study explicitly designed to assess the relationship between task type and imitative ability was conducted by Rogers, Bennetto, McEvoy, and Pennington (1996). These authors assessed imitative performance in high-functioning children and adolescents with ASD across three types of tasks: hand gestures, facial expressions, and pantomime tasks. Furthermore, the symbolic content of facial and gestural tasks was manipulated so that both non-meaningful (e.g., unfamiliar) and meaningful (e.g., familiar) facial expressions and gestures were tested. Although Rogers et al. (1996) found several differences in the performance across task types between children with ASD and children without ASD, the authors did not assess for differences across task types *within* each group (e.g., did children with ASD perform significantly better on hand gestures than facial expressions and was this pattern similar to the children without autism?). In other words, within group differences were not assessed. Nevertheless, this study established the importance of assessing task type and its relationship with imitative performance.

In a similar study, Stone, Ousley, and Littleford (1997) assessed the relationship between type of task and imitative performance in children with ASD, children with developmental delay, and children without ASD or a developmental delay. Participants were approximately three years old and matched based on chronological age (CA), mental age (MA), and language development. Gestural imitation and object imitation were examined under both meaningful and non-meaningful conditions. Unlike Rogers et al. (1996), Stone et al. (1997) assessed within group differences across tasks. These authors found that children with ASD performed significantly better on object imitation tasks than on gestural imitation tasks. Furthermore, meaningful imitation tasks proved easier than non-meaningful tasks for children with ASD. However, the authors did not find a significant effect for group or type of task. Thus, although children with ASD performed significantly worse on all imitative tasks than both control groups, all three groups showed similar profiles of imitative ability in relation to task type. These authors interpreted their results as evidence for a delayed, and not disordered, development of gestural and object imitation. Thus, differences in performance across task types may not be deviant or specific to ASD.

Recent studies of task type provide additional support for the finding that imitative performance varies depending on task type. Rogers, Hepburn, Stackhouse, and Wehner (2003) examined imitative performance of hand gestures, oral-facial tasks, and novel actions on objects. Participants included children with ASD, children with a developmental delay, children with Fragile X syndrome (twenty-eight percent of this sample had a dual ASD diagnosis), and typically developing children. Children in all three clinical groups were approximately three years old and typical children were comparable in MA to the clinical groups. Results of this study indicated children with ASD performed significantly worse on oral-facial imitation and object imitation in comparison to the developmentally delayed and typically developing children. However, hand-gesture imitation tasks did not differentially affect performance across groups. Oral-facial imitation performance was more impaired compared to both object imitation and gestural imitation for participants with ASD. Again, children with ASD performed significantly worse than control groups on only certain types of tasks.

Rogers, Young, Cook, Giolzetti, and Ozonoff (2010) assessed imitative ability in young children with early-onset and regressive onset ASD, children with developmental delays, and typically developing children. The authors manipulated the *effect* of an action, so that in one condition, imitative actions produced a salient and meaningful effect on the environment, whereas in a second condition imitative actions produced a less salient and less meaningful effect. For example, in one task participants imitated the action of shaking a bell, while in the second condition participants imitated the action of shaking a piece of cloth. Thus, the motor action required and spatial positioning of each task remained constant between paired tasks. All tasks involved use of an object. Children with ASD failed more imitative tasks in general and more imitative tasks in the less salient condition than the children with developmental delay and children without ASD and without developmental delay. The analysis of *effect* or meaningfulness of an action is important, as other studies have suggested children with ASD imitate correctly when asked to imitate actions producing a sensory effect (Ingersoll, Schreibman, & Tran, 2003). Roger et.al's study; however, suggests a sensory effect is not required. Simply a meaningful effect enhances imitative performance in children with ASD. These findings provide further evidence against a global imitative deficit.

Thus, although many studies have suggested the existence of an imitative problem in children with ASD (especially in certain task types such as oral facial, meaningless tasks), the general effect of various task variables on imitative ability is unclear. Unfortunately, it is difficult to generalize across studies of imitation in ASD for a variety of reasons. Whiten and Brown (1998) attribute this difficulty to the fact that most studies of imitation in autism have focused on only one or two domains of imitative ability (e.g., either gestural, action on objects, vocal, meaningful, or non-meaningful). In addition, imitation studies have used tasks that vary in complexity, further complicating the interpretations that can be made across studies concerning imitative ability in children with ASD. Other issues that limit the interpretation of these studies include the lack of well matched control groups, and varied instructions (e.g., "Do as I Do," “What can you do with this?”). Finally, the relationship between task type and imitative ability in children with low-functioning autism is often not assessed, as many studies attempt to match children with high-functioning autism with typically developing peers.

Whiten and Brown (1998) attempted to address some of the issues discussed above in a study that used seventy-eight actions across nine different categories of imitative tasks, including verbal imitation, oral-facial imitation, meaningful and non-meaningful gestures, whole body actions (sitting in chair and rocking), pantomimed actions (pretending to brush teeth), and meaningful and non-meaningful actions on objects. Samples included children and adults with ASD, children with mild learning disabilities and typically developing children matched in MA and CA.

Whiten and Brown did not find evidence to support a general deficit of imitation in autism. Children with ASD and adults with autism performed well on imitative tasks, and only young children with ASD performed at significantly lower levels compared to all other groups. Moreover, it was suggested that even the group of young children with ASD demonstrated attempts to imitate. Whiten and Brown’s finding served to challenge the assumption of a general imitation deficit in individuals with autism, and again appeared to suggest that certain conditions (e.g., when participants were provided with the direct instruction to “Do as I do”) appeared to foster imitation in children with ASD. This finding also served to support the notion of delayed imitation in autism, as only the young children with ASD performed in a significantly lower range as compared to matched controls.

Imitative Errors

As previously mentioned, a variety of common errors have been reported across studies of imitation in children with ASD. Reversal errors are the most common type of error identified by researchers (Carpenter, Tomasello, and Striano, 2005; Dewey, Cantell, and Crawford, 2007; Hobson & Lee, 1999; Ohta, 1987; Smith & Bryson, 1998; Whiten & Brown 1998). Often, children with ASD correctly imitate the intended action, but fail to accommodate for the perspective of the demonstrator. Thus, although individuals with autism correctly imitate the goal of an action, they often fail to imitate the self-orientation of actions (e.g., waving so that the palm of the hand is facing the body, rather than away). While reversal errors are described as quite common among children with ASD, others have failed to find significant differences in the number of reversal errors between children with ASD and matched typical controls (Vanvuchelen, Roeyers, & Weerdt, 2007a). Thus the extent to which this error exists, as well as the implications of its occurrence is unclear.

Although the distinction between reversal errors and mirror imitation is inconsistent across studies, "mirror imitation" has often been used to refer to a separate but similar error type. While reversal errors refer to the incorrect orientation of an imitation task (e.g., waving towards the body rather than away), mirroring errors are used to describe imitative acts that occur in an ispilateral motion (e.g., using their right hand when the demonstrator uses their left hand). Typically developing children tend to perform best when asked to imitate as if in a mirror (imitate an action in the same spatial area as the model). However, some authors suggest individuals with ASD fail to take advantage of mirror imitation conditions (i.e., performance does not improve when asked to imitate as if in a mirror rather than in the opposite spatial area as the model) (Avikainen, Wohlschlager, Liuhanen, Hanninen, & Hari, 2003). Yet, others have failed to replicate this effect, and suggest that children with ASD perform *best* during mirror imitation tasks (Hamilton, Bindley, and Frith, 2007; Vanvuchelen et al., 2007a). In addition to reversal errors and mirror imitation, researchers have identified other errors in imitation, including spatial errors (synkinesias), the need for multiple attempts, and partial imitation (Vanvuchelen et al., 2007a). Other authors have also identified the existence of distortion errors (change in amplitude, force, and timing of imitation), incorrect action errors, and body-part-as object errors (e.g., using a finger as a toothbrush when asked to model the symbolic action of pretending to brush teeth) during imitation tasks and when following verbal requests to perform the actions without prior demonstration (Dewey et al., 2007).

Error analyses have also been recently expanded by Rogers et al. (2010) to include the examination of error types in object tasks (previously error analyses were only conducted in studies assessing gestural imitation). These authors assessed for differences in imitation accuracy, bilateral errors (i.e., holding object in only one hand), hand position errors (i.e., grasping the object incorrectly), location errors, movement dynamic errors (i.e., spatial errors), repetition errors (i.e., failing to perform the action an equal number of times as the demonstrator), and emulation errors (i.e., imitation of the goal rather than the form of the action). There were no differences in the number of accuracy errors between children with ASD and the comparison groups; however, the authors found that children with early onset autism imitated more accurately than the regressive-autism group. The authors also found no differences in the pattern of errors displayed by the early onset group, regressive-autism group, developmentally delayed group, and typically developing comparison group. Finally, contrary to established findings in the literature, Rogers et al. (2010) found that children with ASD did *not* display more emulation errors than other groups.

The comparison of error types between children with ASD and typically developing children has allowed researchers to address the question of whether imitation should be categorized as a delay or a core deficit in autism. Current error analyses suggest that common errors in children with ASD (e.g., reversal errors, spatial errors) are also common in typically developing children and in children with other developmental disabilities (Dewey et al. 2007; Hamilton, Bindley, and Frith, 2007; Vanvuchelen et al., 2007a), suggesting imitative difficulties may not be specific to ASD. Furthermore, these findings suggest certain errors may not be evidence of a deviant imitation repertoire in children with ASD. Thus, identifying which errors are committed more commonly by children with ASD as compared to typically developing peers can assist in delineating true imitative problems related to ASD.

The Relationship between Error Type and Theories of the "Imitation Deficit"

Several theoretical accounts exist to explain poor imitative performance in children with ASD. Recently, Vanvuchelen et al. (2007a) suggested the identification of error types can be used to evaluate the validity of many theoretical explanations for the "imitation deficit." Specifically, he distinguished two types of error categories: action production errors and action conception errors. In other words, certain errors (e.g., partial imitation, accuracy of the imitative act) are conceptualized as linked to the action production system, whereas content errors (the production of a different gesture or action) are conceptualized as linked to the action conception system.

More specifically, Vanvuchelen (2007a) hypothesized that spatial errors are linked to the action production system and therefore denote difficulties in producing imitative acts. Spatial imitation errors may also suggest the presence of motor difficulties, providing support of a motor deficit in children with ASD that leads to imitative problems. Partial imitation errors (i.e., poor accuracy) are also linked to the action production system and may reflect motor difficulties or problems completing the imitative act in its entirety.

Although not explicitly defined, many other errors can also be described as “linked” to theoretical explanations of the “imitation deficit.” For example, attending errors and no-response errors are reflective of attending and motivational theories (Vanvuchelen, et al., 2007). These theories suggest at the root of imitation deficits in children with ASD is poor attending behavior and low motivation to complete imitative tasks or interact with the experimenter. In addition to attending difficulties, behavioral (i.e., non-compliance) explanations may serve to explain imitation problems in children with ASD. Although reports of children with ASD refusing to imitate are rare in studies of imitation (Vanvuchelen, et al., 2007) behavioral errors were still coded in order to assess the frequency of non-compliance. Finally, mirroring errors have been linked to the self-other mapping theory which attempts to explain imitation deficit in children with ASD (Rogers & Pennington, 1991). This theory suggests children with ASD are impaired in their ability to map one’s own actions onto the actions of others. Self-other mapping theory implicates impaired self-other representations as the explanatory factor in poor imitative performance among children with ASD. Self-other mapping is also associated with the mirror-neuron theory of imitation in children with ASD, which suggests impaired mirror-neuron systems are related to imitation deficit (Williams, Whiten, Suddendorf, & Perret, 2001). The presence of mirroring errors would suggest a difficulty mapping others actions onto one’s own and perhaps provide support for the mirror-neuron or self-other mapping hypotheses.

Multiple attempt errors are suggested by Vanvuchelen et al., 2007 to be a reflection of motor planning and execution difficulties (i.e., related to the action production system). Although a clearly established link between the multiple attempt error and this explanation has yet to be established in the literature, this error may be important for a variety of reasons. First, the need for multiple attempts in children with ASD is important in designing interventions. If children with ASD perform imitative tasks as well as typical peers, but require more opportunities to do so, then clearly interventions should focus on decreasing the amount of trials needed. Second, if multiple attempts lead to more correct performance, then multiple attempt errors may be suggestive of action production difficulties. Finally, most studies in imitation provide participants with up to three trials to perform the imitative act. Yet, if multiple attempts are not coded, children with ASD and typically developing children may appear to have imitated more similarly than they truly did. For example, an average of three trials may have been presented to the children with ASD when an average of only one trial was necessary for the typically developing group.

Thus, the errors coded in this study were interpreted as a behavioral referent for the several theories currently used to explain imitative difficulties in children with ASD. Likewise, the presence of errors in typically developing children would suggest these errors should not be interpreted as evidence of a distorted imitative repertoire in children with ASD, but perhaps suggest a delayed imitative pattern or the lack of an overall imitative deficit. Table 1 summarizes each error type and the theoretical explanation it was used to test.

Primary Aims of the Current Study

Given the diversity in findings of studies of imitation in autism, it is not surprising that explanatory theories of this phenomenon are also diverse in their hypotheses and assumptions, (and at times even contradictory). Currently, definitive evidence in support of any primary theory of imitation in autism is unavailable, due to the variability in task variables across studies, dissimilar methodology, and variable samples. Additionally, relatively few studies have focused on errors emitted during imitative tasks, and no study has compared the frequency and types of errors emitted across types of imitative tasks. Error analyses have been widely useful in distinguishing between the validity of a variety of theories of imitation and in addressing the delay vs. deviance question. However, these types of studies are generally limited to gestural imitation tasks, despite the fact that many studies use object tasks when assessing the imitative ability of children with ASD. A complete assessment of the types of errors emitted across a variety of imitation task types will allow for a more clear understanding of imitation in general, as well as imitation in children with ASD. Additionally, an analysis of error types across task types may further substantiate the varied profile of imitative abilities in children with ASD across types (e.g., more errors made during facial tasks than during object tasks). Finally, given that certain errors are theorized to correspond to action production errors or action conception errors (Vanvuchelen et al., 2007a), the presence or absence of error types will assist in understanding the nature of imitative difficulties.

The first aim of this study was to assess the pattern of errors emitted across different imitative task types. Three groups of primary tasks were assessed: object imitation tasks, facial imitation tasks, and facial-object imitation tasks (i.e., object tasks performed in the facial area, e.g., using a napkin to dab lips). This latter group of tasks has not been addressed in the literature. However, given the overall finding that facial imitation is impaired relative to object imitation, a cross between these two tasks may assist in understanding why these two task types (facial and object) lead to variable performance. Six types of errors were assessed: 1) the need for multiple attempts, 2) spatial errors, 3) failure to attend (defined by a failure in facing towards the demonstrator's direction during trial presentation), 4) mirror imitation, 5) noncompliance, and 6) no-response. The prevalence of each error across the three task types was examined in order to present a clearer understanding of the types of tasks that produce the greatest difficulty for children with ASD. It was hypothesized that higher error rates would correspond to task types that presented the most difficulty for both groups. Thus, higher error rates were expected in the facial imitation task type, followed by the object-facial task, with the object tasks corresponding to the least number of errors.

The second aim of this study was to explicate the relationship between level of intellectual functioning and the frequency of errors emitted by children with ASD. In order to assess differences in the number of errors emitted by children with ASD and typically developing children, it was necessary to parse out the effect of IQ. Thus, this analysis allowed for a clearer understanding of the imitative difficulties that are autism specific, rather than a reflection of intellectual disabilities.

The third aim of this study was to compare accuracy across imitation tasks between groups. Thus, the accuracy in imitative performance of high-functioning children with ASD (IQ >70), low-functioning children with ASD (IQ <70), and typically developing children was compared. Accuracy scores were obtained for the complete battery of imitative tasks and for each of the three task types. Sample sizes in this study did not allow for a statistical analysis of the differences in performance across task types or the overall battery. However, visual inspection methods were used to surmise the relationship between task type and performance across participant groups.

Methods

Participants

This study used archival data that were part of a larger research project conducted by Romanczyk, Gillis, Eagle, and Callahan from 2007-2009 at the Institute for Child Development in Binghamton, New York. Thirty-one children with ASD receiving special education services at the time of data collection were recruited to participate. The age range of the group was 3-12 years old (M = 6.79, SD = 2.73). Twenty-two low-functioning (IQ<70) and nine high-functioning (IQ>70) children participated in the study (M_{IQ} = 59.23, SD = 24.36, IQ Range = 29-130). Gender characteristics for this group of participants appear representative of an ASD sample (five females and 26 males). All of the females were in the low-functioning group. In order to compare the high-functioning children with ASD to typically developing children, eighteen typically developing children were later recruited from the Auburn-Opelika area as part of this current study. These children were not diagnosed with a developmental disability or an ASD. Mann Whitney U tests were used to assess differences in age, IQ, and VIQ (Verbal IQ). Typically developing children and high-functioning children with ASD were matched in age, Z = -.077, p = .94. However, the typically developing children had a significantly higher IQ (termed Full Scale IQ on the WPPSI-III and IQ Composite on the KBIT-2) and VIQ scores than the high-functioning children with ASD , Z = -2.42, p = .015, Z = -2.53, p = .011, respectively. Given this difference, statistical procedures were utilized to control for the effects of IQ when comparing groups. The comparison group was comprised of 11 typically developing females and 7 typically developing males; thus, gender differences between the two groups also existed within our sample. Age ranges were approximately equally represented across the low-functioning and high-functioning groups. See Table 2 for participant characteristics.

Measures

The *Kaufman Brief Intelligence Test, Second Edition* (KBIT-2; Kaufman & Kaufman, 2004) or the *Wechsler Preschool and Primary Scale of Intelligence-Third Edition* (WPPSI-III; Wechsler, 2002) was used to assess for cognitive abilities. Both measures are frequently used in research with children with ASD. The KBIT-2 is a brief measure of the verbal and nonverbal intelligence of children (age 4 and above), adolescents, and adults. The KBIT-2 takes approximately 15 to 30 minutes to administer and is comprised of three scores: Verbal, Nonverbal, and IQ Composite. The KBIT-2 was standardized using a sample of 2,120 individuals across several race/ethnicity categories, geographic regions, and educational level (Kaufman & Kaufman, 2004). The KBIT-2 demonstrates high internal consistency, with average reliability coefficients of .88 (verbal), .85 (nonverbal), and .91 (IQ Composite) for children ages 5-10. Validity for the KBIT-2 has also been well established. IQ Composite scores on the KBIT-2 and Wechsler scale scores are highly correlated, .76 (WISC-III), and .77 (WISC-IV).

To assess the cognitive abilities of children ages younger than 4 years old, the WPPSI-III was administered. As with the KBIT-2, three primary scores are obtained: the Full Scale IQ (FSIQ), Verbal IQ (VIQ), and Performance IQ (PIQ). The WPPSI-III was standardized using a diverse and representative sample of 1,700 children in the United States, with 200 children included at each 6-month interval between ages 2 and 6. Reliability for each subtest of WPPSI-III is acceptable to excellent across all ages (.83 to .95), and internal consistency coefficients for FSIQ are excellent (.95 or higher for all age groups). Validity for the WPPSI-III is also well established, and FSIQ scores on the WPPSI-III correlate highly with other measures of similar constructs for preschoolers, .87 for the Differential Ability Scales (Elliot, 1990), and .80 for the Bailey Scales of Infant Development-Second Edition (BSID-II; Bailey, 1993) (Wechsler, 2002). Administration of the WPPSI-III takes approximately 30 minutes.

In order to assess for the presence and severity of an autism spectrum disorder the *Childhood Autism Rating Scale* (CARS; Schopler, Richler, & Renner, 1986) was used. The CARS is an observational measure designed to distinguish children with ASD from children with other developmental disabilities, and to provide a measure of the severity of autism symtomatology. The CARS contains fifteen 4-point scales for rating a child's behavior as *(1) within the normal limits* to *(4) severely abnormal.* Scores range from 0-60 with scores of 30 or greater suggesting the presence of an ASD. Cutoff scores derived from the CARS are also used to distinguish between non-autistic, mild to moderate autistic, and severely autistic. The CARS is extensively used as a prediagnostic measure, and validity and reliability estimates for the CARS range from moderate to excellent. The average CARS score for the children with ASD in this sample was 35.07 (SD = 7.48, Range = 21.50 – 50.50). Thus, a wide range of ASD severity was represented in this sample. In addition to the CARS, a DSM-IV-TR diagnostic checklist was used to obtain a research diagnosis. The checklist assesses symptoms corresponding to the three primary domains of autism (i.e., social, communication, repetitive behavior), and differentiates among Autistic Disorder, Asperger's Disorder, and PDD-NOS. All participants in the high-functioning and low-functioning groups met the research diagnosis for an ASD. Diagnoses were confirmed based on a review of medical and school records and completion of the diagnostic checklist administered by doctoral level students and a clinical psychologist. See Appendix A for the diagnostic checklist.

Legal guardians of participants also provided demographic information, including the child's gender, race/ethnicity, age, and socioeconomic background. Completion of the questionnaire took approximately 5 minutes.

Procedures

Participants completed a series of 15 imitation tasks: 5 object imitation tasks, 5 facial-object tasks, and 5 facial tasks. All tasks can be defined as meaningful, as they were highly familiar tasks and expressions. See Appendix B for the list of imitation tasks. Participants observed a demonstrator perform the task. Following the model, participants were given access to the object (for object and facial-object tasks) and given the instruction, "You Do It." Participants were given 15 seconds to respond. If participants did not respond correctly, the model demonstrated the act for a second time, and repeated the instruction. The same procedure was repeated a third (and final) time if necessary. For correct responding, short verbal reinforcement was provided (e.g., "Good"). The entire imitation battery lasted approximately 15 minutes.

For each task, the best performance was chosen and scored for accuracy. Accuracy scores ranged from 0 to 4, with increasing scores denoting increasing accuracy. Thus, for the entire battery the possible range of scores was 0 to 60. A complete list of the scoring criteria can be found in Appendix C.

The best trial for each participant was also coded for errors. Six error types were coded and analyzed: multiple attempts (the need for multiple trials), spatial errors (performing the task in the incorrect spatial area), failure to attend (a lack of orienting towards the demonstrator during the entire trial presentation, approximately 3-5 seconds), mirror imitation (performing the act in the ipsilateral area), non-compliance, and no-response. Errors were coded as 0 or 1 (0 if the error did not occur and 1 if the error occurred) and then aggregated for each task type (e.g., total number of spatial errors for facial-object tasks, etc.) for each participant. Additionally the frequency of each error type across each task type (e.g., attending errors for object tasks, attending errors for facial-object tasks, and attending errors for facial tasks, etc.) was then computed for each participant. It should be noted that the multiple attempt, failure to attend, non-compliance, and no-response error were possible across all 15 tasks, whereas the spatial error and mirroring error were not. The spatial error was possible for only 10 tasks (those which used an object); thus, spatial errors were not possible for facial imitation tasks. The mirroring error was possible for only five tasks (Tractor, Tiger, Mirror, Toy Pony, and Maraca). Thus, only two object tasks allowed for the opportunity to commit a mirroring error, while three object-facial tasks allowed for the opportunity to mirror the demonstrator. Given the unequal opportunity to mirror across tasks, the relationship between the mirroring error and task type was not assessed.

At least two independent observers coded the imitation sessions according to the criteria described above. Additionally, the first author coded 40% of all sessions (20 out of 49) to assess interobserver agreement (IOA). IOA was calculated by dividing the number of agreements by the total number of agreements plus disagreements. IOA was examined for both the accuracy coding and error coding, given possible differences in coding accuracy across these two dimensions. Across all sessions, the mean IOA for accuracy coding was .81 (ranging from .61 to .87) and the mean IOA for error coding was .89 (ranging from .84 to .92).

A multilevel model (MLM) was used to determine differences in errors across participant groups and the relationship between error types and task types. A MLM approach was preferred over other statistical procedures for a variety of reasons. The nature of the data was hierarchical, creating a complex error structure in which task and type were crossed within participants. Thus, the assumption of nonindependence of errors was clearly violated (examination of the variances and covariance matrix revealed non-independence of errors, substantiating the decision to use a MLM approach). Although many statistical procedures correct for nonindependence of observations; they often merely remove the effects of clustering. MLM, however, adjusts standard errors to accommodate for clustering and thus corrects for non-independence of observations while still allowing researchers to compare group effects (Tabachnick & Fidell, 2006). In addition, MLM allows means and slopes to vary across groups (e.g., the relationship between each error and each task type was allowed to vary between the high-functioning group, low-functioning group, and typically developing group) (Tabachnick & Fidell, 2006). There is no reason to assume that the relationship between each error and task type would be equal across groups; thus, a MLM approach eliminated the need for this atheoretical assumption. MLM also allowed us to assess differences in errors among the three groups (i.e., high-functioning, low-functioning, and typical developing children) and the relationship between IQ and the number of imitation errors emitted simultaneously within a single model.

The dependent variable in our model was the number of errors and the independent variables were level of functioning, task type (object, object-facial, facial), and group membership (children with ASD or typically developing children). Level of functioning was calculated by subtracting 70 from each IQ score, thus, providing a deviation score indicating the distance between an individual and the cutoff IQ score for the low-functioning and high-functioning groups. Task types and group membership were dummy coded so as to facilitate interpretation and allow for a comparison of group means. All participants completed at least 14 of the 15 tasks and missing data were estimated by the MLM procedure. No significant outliers were present for level of functioning (IQ) and this variable appeared approximately normal.

Skewness and kurtosis levels were in the acceptable range and the data met assumptions of homoscedasticity.

Results

Imitation Accuracy

Mean total scores for accuracy on the imitation battery and mean accuracy scores for each task category for the high-functioning, low-functioning, and typically developing group are presented in Figure 1. Differences between groups were not investigated due to low sample size and unequal sample sizes across groups. Nevertheless, differences between the low-functioning group and both the high-functioning and typically developing children are evident from visual inspection of Figure 1. Difference in accuracy across tasks *within* groups was also not assessed due to low sample size. Yet, visual inspection of Figure 1 suggests that for high-functioning children with ASD and typically developing children the type of task did not strongly affect performance. Low-functioning children, however, performed differentially across task types, and demonstrated most difficulty with the facial imitation tasks.

Error Analysis

Errors appeared to differ greatly depending on group membership. For a summary of the mean number of errors emitted by each group membership see Figure 2.

A more detailed analysis of error differences was assessed using a multilevel model analysis. The baseline model (no predictors) generated the mean values for all participants in the sample for each error type by each task type (i.e., multiple attempt errors in the object task) and tested whether each mean value was significantly different from zero. The grand means (entire sample mean) for all 6 errors (multiple attempts, spatial, failure to attend, mirroring, non-compliance, and no-response) were significantly different from zero (*p* < .05) in all task types except for the no-response error. The grand mean for the no-response error was significantly different from zero in only one condition: facial imitation tasks. Thus, in the object and object-facial tasks, the grand mean for the no-response error was not significantly different from zero. Grand means for each error in each task type are presented in Table 3. The most common error was multiple attempts in all three task categories.

The baseline model also generated pairwise comparisons of the mean difference in errors across task types. The grand mean for two error types were significantly different across task types. There were significantly more multiple attempt errors in the object-facial task than the object task, $t(48) = -.65$, $p < .01$, and significantly more no-response errors in the facial task than the object facial task, $t(48) = .57$, $p < .01$. All other task comparisons were not significantly different at this stage of the model (grand means).

The second model introduced dummy coding for group membership (1 = ASD, 0 = typically developing). This generated grand means for the entire sample of ASD participants (high-functioning and low-functioning, N = 31) and typically developing participants (N = 18). The second model also tested the differences in error means across task types for both groups and differences between groups for each error x task combination. Results are divided by group membership in order to facilitate interpretability.

All analyses for the typically developing group tested whether the mean number of errors was significantly different from zero. Typically developing children did not make a significant number of multiple attempt errors, spatial errors, attending errors, non-compliance errors or no-response errors in any of the task types. However, the typically developing group made a significant number of mirroring errors in both the object task, $t(47) = 1.44$, $p < .001$ and the object-facial task, $t(46.08) = .90$ $p < .001$. The difference in the number of mirroring errors across tasks was not assessed given the unequal opportunities to mirror in these two task types. Results for the typically developing group are presented in Table 4.

All means for the ASD group were compared with means for the typically developing group, such that significant differences indicate a difference in the means between both groups (rather than a difference from zero as was tested for the typically developing group). Children with ASD (high-functioning and low-functioning participants) made significantly more errors than the typically developing children in the following error categories: multiple attempts across all three task types, spatial errors in the object task and object-facial task, attending errors in the facial task, and no-response errors in the facial task. Children with ASD made significantly fewer mirroring errors than the typically developing children in the object task. In all other error x task combinations, children with ASD did not make significantly more errors than the typically developing children. Results for the entire ASD sample are presented in Table 4.

Pairwise comparisons for the entire sample of children with ASD were also conducted in order to analyze differences in the number of errors produced by children with ASD across the three task types. Children with ASD made significantly more multiple attempt errors in the object-facial task than the object Task, $t(47) = -.94$, $p < .01$. All other pairwise comparisons were non-significant; thus for the entire ASD sample errors were approximately equally distributed across task types.

The third and final model introduced the level of functioning variable which served to control differences in IQ across groups. This model also explicated the relationship between IQ and the number of errors. As expected, after controlling for level of functioning, several differences in the frequency of errors between the children with ASD and typically developing children were no longer significant. However, the mean number of multiple attempts in the object-facial and facial tasks continued to be statistically significant after controlling for level of functioning, $t(46) = 2.28$ $p < .05$ and $t(46) = 1.48$, $p < .05$, respectively.

The relationship between level of functioning and the number of errors was significant for a large proportion of errors. Table 5 reports the increase or decrease in the number of errors predicted for each one point increase in IQ points for a child with an ASD. Thus, the mean for the children with ASD group would be added or subtracted to this value to determine the predicted number of errors for that child. The relationship between IQ and the number of errors was significant for the spatial and mirroring errors in the object task, the spatial error in the object-facial task, and all errors assessed in the facial task. After controlling for IQ only one error type was significantly different across task types for children with ASD. The mean for the multiple attempt error was significantly greater in the object-facial task than the object task for children with ASD, $t(46) = 1.01$, $p < .01$. All other error types were not significantly different across task types after controlling for IQ in the ASD group.

Discussion

The primary purpose of this study was to further elucidate reasons children with ASD have difficulty imitating actions and facial expressions. Prior studies of imitation have focused heavily on whether or not children with ASD can imitate certain tasks, rather than explaining the primary errors children with ASD make that lead to deficits in imitation. This study focused specifically on the types of common errors children with ASD emit across three types of imitation tasks: object tasks, object-facial tasks, and facial imitation tasks. The types of errors assessed were derived from previous error analysis conducted in gestural imitation studies (Vanvuchelen et al., 2007a) and correspond to different theoretical explanations of the imitation deficit in children with ASD. Six primary errors were selected for this study: 1) multiple attempts, 2) spatial errors, 3) failure to attend, 4) mirroring, 5) non-compliance, and 6) no-response.

Multiple Attempts and Spatial Errors

Children with ASD emitted more multiple attempts in the object-facial task than the object task. This same pattern was not observed for the typically developing children, suggesting object-facial tasks are uniquely difficult for children with ASD. Children with ASD (when including both low-functioning and high-functioning groups) also produced significantly more multiple attempt errors than typically developing children in all three task types. Similarly, although typically developing children did not emit a significant number of spatial errors in any task type, children with ASD produced significantly more spatial errors in the object and object-facial tasks than the typically developing group.

The significant number of multiple attempts and spatial errors point to an action production or motor deficit in children with ASD that may serve to explain part of the imitation difficulties of children with ASD. Studies of motor development have suggested that children with ASD demonstrate abnormalities in fine and gross motor skills (Baranekl, 2002; Jones & Prior, 1985; Minshew, Goldstein, & Siegel, 1997; Noterdaeme, Mildenberger, Minow, & Amorosa, 2002) and these deficits have been linked to poor imitative performance (Minshew, Sweeney, Bauman, & Webb, 2005; Vanvuchelen, Roeyers, & Weerdt, 2007b). The presence of spatial errors and repeated attempts to complete an imitative task suggest difficulty with motor movements. Multiple attempt errors may also be due to poor attending, non-compliance, or behavioral difficulties. Nevertheless, the need to perform imitative acts several times suggests an imitative deficit in children with ASD. Unfortunately, this study did not assess whether multiple attempts led to better performance. That is, the relationship between accuracy and multiple attempts was not assessed. If multiple attempts led to greater accuracy, this may serve to corroborate a motor-explanation (action-production) as more motor practice may serve to diminish imitative differences in children with ASD. Furthermore, it should be noted the presence of motor deficits was not assessed in this study; rather, the spatial error served as an indication of motor difficulties. Future studies may focus on assessing the extent to which spatial errors predict motor impairments in children with ASD.

Failure to Attend and No-Response Errors

Interestingly, more attending and no-response errors were emitted by children with ASD in the facial tasks, but were not emitted more frequently than typically developing children in any other task type. This suggests that attending and behavioral difficulties only served to impede performance in the facial imitation tasks. Additionally, this finding challenges the assumption that one overarching theory of imitative difficulties can be served to explain all imitative behavior in children with ASD. Conversely, it appears that across different task types, different impairments may serve to explain poor imitative performance. Within this study, attending problems do not explain differential performance in the object and object-facial tasks. Rather, they serve to explain the imitation problems children with ASD demonstrated in the facial imitation tasks. This notion presents an onerous task for imitation researchers who have attempted to identify an all-encompassing theory of imitation and imitation problems in children with ASD that fails to take into account the various types of imitation tasks. The presence of more attending and no-response errors in the facial imitation tasks also serves to corroborate pervious research pointing to an especially impaired ability to imitate facial expressions in children with ASD (Rogers & Williams, 2006).

Mirroring Errors

Typically developing children made a significant number of mirroring errors in the object and object-facial tasks suggesting that mirroring is a developmentally appropriate error. This finding suggests that mirroring errors should not be used as an indicator of an imitation deficit in children with ASD and perhaps implies a weakness in the mirror-neuron/self-other mapping explanation of poor imitation. Clearly, typically developing children also have difficulty with self-other representations or do not perceive this as an important part of imitation tasks. It is possible that both typically developing children and children with ASD imitated as if in a mirror because this required less response effort than imitating in the contra-lateral space of the demonstrator. Studies of mirror imitation have led to contradictory results with some studies suggesting children with ASD imitate best when asked to imitate as if in a mirror (Hamilton et al., 2007) with others reporting lack of improved performance in these conditions (Avikainen et al., 2003). Nevertheless, the results of this study suggest that mirroring may not be as deviant as once thought and may instead be a developmentally appropriate imitation "error."

In contrast to typically developing children, children with ASD did not emit a significant number of mirroring errors and mirrored much less than the typically developing children. One possible explanation for this finding is that children with ASD emitted several other errors which competed with mirroring errors. For example, children with ASD emitted more spatial errors in the object and object-facial tasks than typically developing children, which may have inhibited a tendency to mirror in this group. Given the tendency for typically developing children to mirror more frequently than children with ASD; mirroring errors were inversely related to IQ. However, even after controlling for IQ, a significant difference in the number of mirroring errors between typically developing children and children with ASD remained. This finding suggests that both low-functioning and high-functioning children with ASD did not emit a significant number of mirroring errors in any of the imitation task types.

Non-Compliance Errors

Non-compliance was not observed more frequently in the children with ASD when compared to typically developing children in any task types. This suggests behavioral difficulties cannot serve to fully explain poor imitation performance in children with ASD. Nevertheless, non-compliance in the facial task was negatively correlated with IQ, suggesting children with low-functioning ASD emitted more non-compliance errors than children with high-functioning ASD and typically developing children.

The Effect of Level of Functioning

Many studies have suggested that impaired imitation is merely a reflection of low IQ in children with ASD. Thus, in order to identify a "true" imitation deficit in children with ASD, many authors suggest a comparison between high-functioning children with ASD and typically developing children with ASD is needed. Although this approach oversimplifies imitative difficulties and suggests low-functioning children with ASD are not distinct from high-functioning children without ASD, the relationship between IQ and imitation is essential in understanding autism-specific impairments in imitation. After controlling for IQ differences between the children with ASD and typically developing group, many differences in errors were no longer significant. Multiple attempt errors were the only error that remained to be significantly different between typically developing children and children with ASD. However, this error was only significant in two task types: object-facial and facial imitation tasks. This finding serves to suggest that even high-functioning children with ASD needed to perform the task multiple times and were impaired in their imitative abilities.

Additionally, the significant number of multiple attempt errors points to a weakness in the methodology of imitation studies. Most studies of imitation in children with ASD allow up to three trials and then use the best trial to compare performance across groups (as was done in this study). However, if multiple attempts are not accounted for, the performance of high-functioning children with ASD is likely exaggerated in comparison to their typically developing peers. Given the finding that after controlling for IQ, more multiple attempt errors were emitted by children with ASD, it may benefit researchers to control for the number of trials presented for each group in order to present a more accurate picture of the imitative difficulties in both high-functioning and low-functioning children with ASD.

MLM analysis allowed us to assess the relationship between IQ and the number of errors emitted. There was a significant negative relationship between IQ and the number of errors emitted in all of the facial imitation tasks. This suggests that as level of functioning decreased, more errors were emitted in the facial tasks. Again, this finding corroborates past findings of a more deficient imitative repertoire with respect to facial tasks in children with ASD (Rogers & Williams, 2006). IQ was also negatively related to spatial errors in the object and object-facial tasks, suggesting that low-functioning children with ASD emitted more spatial errors in these tasks than high-functioning children with ASD or typically developing children.

Limitations

The findings presented in this study should be interpreted in light of several limitations. First, demographic differences between the typically developing children sampled and children with ASD sampled exist. The children with ASD in this study participated in this study approximately 2 years earlier than the typically developing children in New York. In contrast, typically developing children completed this study in 2009-2010 and were sampled from schools within the Auburn-Opelika area in Alabama. Although demographic differences are not likely as an explanation of imitation differences, a more stringent analysis may have sampled children from the same area. Unfortunately, due to difficulties recruiting children with ASD in rural areas this was not possible.

Another potential limitation of this study is the small sample size of children with high-functioning autism. Although we attempted to control for this issue by using an MLM approach, future studies may attempt to analyze differences between groups more directly. The low sample size for the HFA group also prohibited the analysis of differences in performance between groups. Related to this problem, this study included a wide range of children with ASD. While this serves to more accurately represent the variability in autism across children, such a wide range of functioning and severity of autism may serve to limit the interpretations of this study.

As mentioned earlier, the relationship between performance and error types was not assessed. Thus, it is not known if errors led to more accurate performance in children with ASD. This type of analysis, however, would be beneficial in light of the delay vs. deviance question in imitation. Thus, errors which led to more accurate performance may be indicative of a delayed imitation pattern, whereas errors leading to continued incorrect performance may suggest a more deviant pattern of imitation in children with ASD. Future error analyses may benefit from such an assessment. Furthermore, although accuracy scores were recorded, differences in performance scores across groups in each task type were not assessed due to limitations in sample size (rather a visual inspection analysis was utilized). As only nine high functioning participants with ASD were included in this sample, future research may focus on increasing the sample size of this study and conducting a statistically analysis of difference in accuracy scores across task types.

Finally, although errors coded in this study were as precise as possible, future research could focus on defining errors in a more specific, operationalized manner. Specifically, attending in this study was not assessed using eye tracking software; therefore accuracy of this error may be improved in future research. Nevertheless, observer coding of “failing to attend” is often used in studies of imitation and often provides valuable information regarding imitative performance (generally this is the most common method used in the literature).

Future Areas of Research

In addition to addressing some of the limitations above, future research may focus on conducting error analyses for types of imitative tasks that are known to produce difficulties for children with ASD. For example, in this study only meaningful tasks were used; however, meaningless (i.e., unfamiliar) tasks have been found to lead to decreased imitative performance in children with ASD. Additionally, tasks that do not produce a “meaningful effect” (e.g., a sensory effect) have been found to be related to imitation deficits. Thus, an analysis of the types of errors produced during more difficult imitative tasks may lead to a more comprehensive understanding of the types of problems these tasks pose for children with ASD.

Another potential area of future research may include developing error types more specific to certain task types. For example, only three errors were appropriate to the facial imitation task. This is largely due to the fact this study adopted previously established error types from gestural imitation studies. However, future research may focus on developing error types specific to facial imitation tasks or traditionally less tested imitation task types (i.e., object-facial imitation tasks).

Conclusion

Error analyses are becoming more common in imitation research in children with ASD. This study attempted to extend previous analyses of error types to different task types. This study is the first study to assess the frequency of errors in object-facial tasks and facial imitation tasks. Differences in error types appeared to differ depending on the type of imitation task, suggesting that task variables should be assessed when conducting error analyses. Differences in errors across task types contradict the notion of an omnibus theory of imitation deficits in children with ASD and suggest the need for theoretical accounts that can explain divergent performance across tasks.

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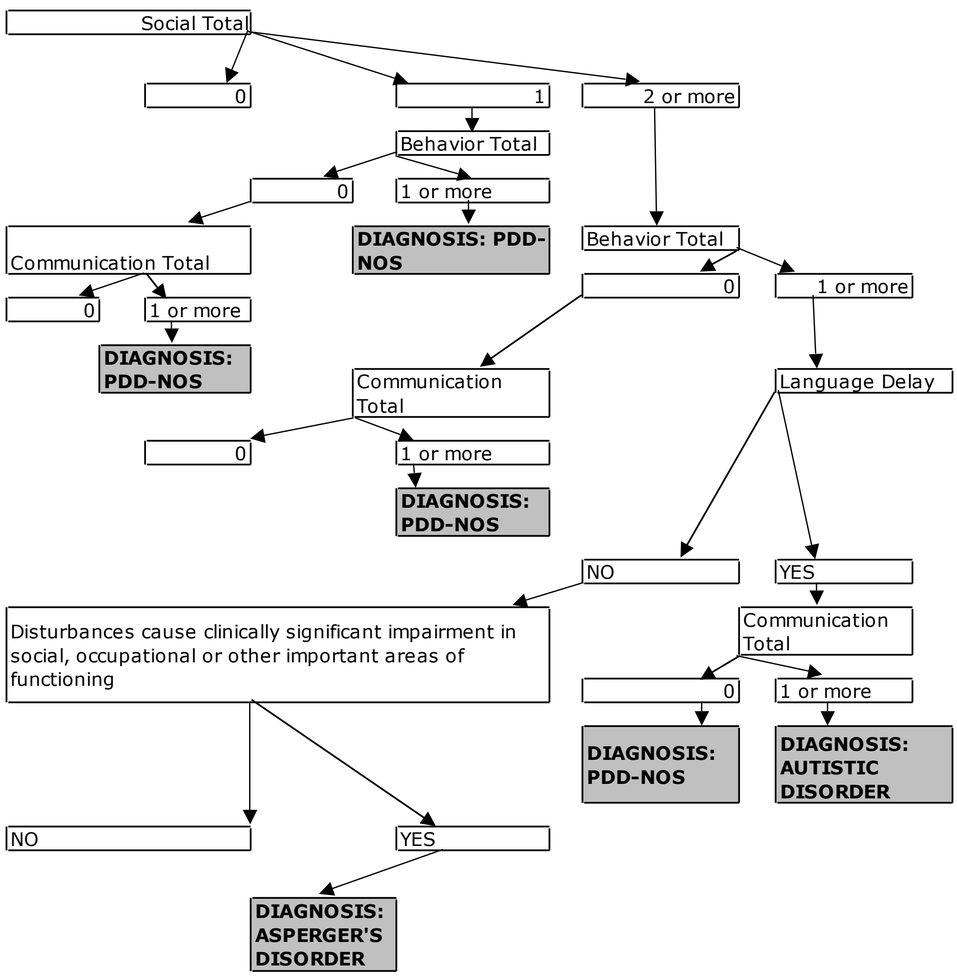
Appendix 1

Diagnostic Checklist

Child/Participant #:__________________ Rater:___________ Date:__________

Social Total:	
Communication Total:	
Behavior Total:	



DIAGNOSIS:______________________

Appendix 2

Imitation Battery

Trial #	Imitation Action	Approximate Correct Response
1	Push toy tractor in a horizontal motion	Tractor must move to the left or right at least one inch.
2	Stack on block on top of another block	Stack on block on top of another block
3	Hit toy hammer on desk once	If hits hammer more than 1x, still score as correct
4	Feed baby doll with toy bottle	Bottle must be presented in correct orientation to baby's mouth area.
5	Bounce stuffed toy tiger three times in horizontal direction	Bounce tiger at least once
6	Pretend to take a drink out of plastic/paper cup.	Cup should be lifted to mouth area.
7	Bring toy mirror up to right side of face, looking at mirror	Mirror lifted to face (doesn't matter which side).
8	Use napkin to dab lips/mouth area	Bring napkin to face area
9	Bring toy pony up and touch (briefly) your cheek	Pony touch face area
10	Bring maraca to side of face and shake twice	Shake at least once near face.
11	Smile with teeth exposed (happy facial expression)	Smile with/without teeth
12	Make a sad face by protruding lower lip and turning mouth downwards	Protruding lower lip and turning mouth downwards
13	Open mouth with "oooo" motion (surprised facial expression); eyes widened	Mouth rounded to "O" position, eyes widened.
14	Make an angry face (purse lips, furrow brow, squint eyes)	purse lips, furrow brow, squint eyes
15	Look down to where datasheet is (move eyes downward) and then back up at child	Orient head downward OR at sheet.

Appendix 3

Accuracy and Error Definitions

Objects	
Tractor	Correct: Participant pushes tractor to opposite side of the table in a left and right motion 1 time (or more) and back to the target position, holding the tractor the entire time
	A+ 1)Pushes tractor to opposite side (either left or right) and lets go of tractor A+ 2)Participant touches tractor but does not move to either left or right A+ 3) Manipulate tractor in a way that is not described above E1 (Need for Multiple Attempts) E2 (Spatial Error, Movement of tractor on area of table NOT used by the demonstrator) E3 (failure to attend, participant does not look in the demonstrator's direction during trial presentation) E4 (noncompliance; behavioral error) MI (Participant mirrors the demonstrator's movement, i.e., performs movement in same spatial area as demonstrator)
Blocks	Correct: Participant picks up one block and places it on top of the other (does not matter which block is on top)
	A+ 1) participant puts blocks side by side A+2) participant puts blocks close together, but not touching A+3) participant manipulates blocks in a way not described above E1 (Need for Multiple Attempts) E2 (Spatial Error, Movement of blocks on area of the table NOT used by the demonstrator) E3 (failure to attend, participant does not look in the demonstrator's direction during trial presentation) E4 (noncompliance; behavioral error)
Hammer	Correct: Participant holds hammer and hits head of hammer 1 time on table
	A+1) participant holds hammer and hits head of hammer more than 1 time on table A+2) bang hammer, not with hammer head A+3) participant manipulates hammer in way not described above E1(Need for Multiple Attempts) E2 (Spatial Error, Movement of hammer in an area of the table NOT used by the demonstrator) E3 (failure to attend, participant does not look in the demonstrator's direction during trial presentation) E4 (noncompliance; behavioral error)

Baby Bottle	Correct: participant takes bottle and puts the tip of bottle in the face area of doll
	A+1)participant picks up baby and brings bottle to the face area A+2) touch bottle to any part of the baby that is not face area A+3) participant picks up baby or bottle and manipulates in way not described above E1(Need for Multiple Attempts) E2 (Spatial Error, Movement of hammer in an area of the table NOT used by the demonstrator) E3 (failure to attend, participant does not look in the demonstrator's direction during trial presentation) E4 (noncompliance; behavioral error)
Tiger	Correct: Participant holds the tiger and bounces the tiger 2X to left
	A+1) 1 bounce or > 2 bounces to left A+2) 1 bounce of >2 bounce *not* to the left A+3) Slide tiger to left or in any other direction E1 (Need for Multiple Attempts) E2 (Spatial error, Movement of tiger in an area of the table NOT used by the demonstrator E3 (failure to attend, participant does not look in the demonstrator's direction during trial presentation) E4 (noncompliance; behavioral error) MI (Participant mirrors the demonstrator's movement, i.e. performs movement in same spatial area as the demonstrator)
Objects in Facial Area	
Cup	Correct: participant picks up cup and touches to mouth
	A+1)participant picks up cup and touches cup to facial area (NOT mouth) A+2)participant picks up cup A+3) participant manipulates cup in way not described above E1 (Need for Multiple Attempts) E2 (Spatial Error, participant touches but does not pick up cup of picks up cup and brings to area other than mouth) E3 (failure to attend, participant does not look in the demonstrator's direction during trial presentation) E4 (noncompliance; behavioral error)
Mirror	Correct: participant picks up mirror and brings to eye level on right side of head
	A+1) participant picks up mirror and brings to any face area A+2) participant picks up mirror A+3) participant manipulates mirror in way not described above E1 (Need for Multiple Attempts) E2 (Spatial Error, participant touches mirror but does not move mirror from the table, or participant picks up mirror but does NOT bring to facial area) E3 (failure to attend, participant does not look in the demonstrator's direction during trial presentation)

	E4 (noncompliance; behavioral error) MI (Participant mirrors the demonstrator’s movement)
Napkin to Mouth	Correct: participant picks up napkin and touches to mouth
	A+1) participant picks up napkin and brings to facial area, but does not touch mouth A+2) participant picks up napkin but does not bring to facial area A+3) participant touches napkin but does not move off table E1 (Need for Multiple Attempts) E2 (Spatial Error, participant touches napkin but does not move napkin off from the table, or participant picks up napkin but does NOT bring to facial area) E3 (failure to attend, participant does not look in the demonstrator’s direction during trial presentation) E4 (noncompliance; behavioral error)
Toy Pony	Correct: participant picks up pony and touches to cheek
	A+1) participant picks up pony and touches to facial area other than cheek A+2) participant picks up pony and brings off table A+3)participant touches pony but does not move off table E1 (Need for Multiple Attempts) E2 (Spatial Error, participant touches pony but does not move pony from the table, or participant picks up pony but does NOT bring to facial area) E3 (failure to attend, participant does not look in the demonstrator’s direction during trial presentation) E4 (noncompliance; behavioral error) MI (Participant mirrors the demonstrators movement)
Maraca	Correct: participant holds up maraca and shakes it by right side of head 2 times
	A+1) participant shake maraca 1 time of more than 2 times or continued shaking to right side of the head A+2) shake maraca anywhere near the face A+3) bring maraca up without shake E1 (Need for Multiple Attempts) E2 (Spatial Error, participant touches maraca but does not move maraca from the table, or participant picks up maraca but does NOT bring to facial area) E3 (failure to attend, participant does not look in the demonstrator’s direction during trial presentation) E4 (noncompliance; behavioral error) MI (Participant mirrors the demonstrator’s movement)
Facial Expressions	
Smile	Correct: participant's lips curve upward forming a smile exposing teeth
	A+1) smile not exposing teeth A+2) opens mouth A+3) forms facial expression other than smiling E1 (Need for Multiple Attempts) E2 (N/A) E3 (failure to attend, participant does not look in the demonstrator’s direction during trial presentation) E4 (noncompliance; behavioral error)

Sad Face	Correct: Participant protrudes lower lip, looks down, and head tilt down
	A+ 1) protrudes lower lip without looking down or head tilt A+ 2) just look down with head tilt without protruding lower lip A+ 3) participant exhibits other "sad" behaviors (e.g., wiping tears, pretending to cry, whimpers, etc) E1 (Need for Multiple Attempts) E2 (N/A) E3 (failure to attend, participant does not look in the demonstrator’s direction during trial presentation) E4 (noncompliance; behavioral error)
Surprised	Correct: Participant widens eyes and opens mouth to make an "O" shape
	A+1) participant makes an "O" shape with mouth, but does not widen eyes A+2) participant widens eyes but does not make an "O" shape with mouth A+3) forms facial expression other than surprised (e.g., smiling) E1 (Need for Multiple Attempts) E2 (N/A) E3 (failure to attend, participant does not look in the demonstrator’s direction during trial presentation) E4 (noncompliance; behavioral error)
Angry	Correct: participant furrows eyebrows and tightens lips
	A+1) participant tightens lips, but does not furrow eyebrows A+2) participant furrows eyebrows A+3) participant forms facial expression other than angry E1 (Need for Multiple Attempts) E2 (N/A) E3 (failure to attend, participant does not look in the demonstrator’s direction during trial presentation) E4 (noncompliance; behavioral error)
Look Down	Correct: participant's head moves downward towards the table OR towards the data sheet
	A+1) participant looks down towards the table OR Sheet, but does not move head A+2) participant moves head in any direction E1 (Need for Multiple Attempts) E2 (N/A) E3 (failure to attend, participant does not look in the demonstrator’s direction during trial presentation) E4 (noncompliance; behavioral error)

Table 1

Description of Errors and Associated Theory

Error Type	Definition	Example	Associated Theory
Multiple Attempts	The need for multiple presentations of the imitation trial	Requiring two trials before performing the imitative act correctly	Action production/Motor Deficits; yet, potentially unclear relationship with any one theoretical explanation
Spatial Errors	Performing the act in a different spatial area than the demonstrator	Performing the act on the table when the demonstrator performed the act near their head	Action production/Motor Deficits
Failure to Attend	Failing to look in the direction of the demonstrator during the entire duration of the imitative act (approximately 5 seconds)	Looking down while the demonstrator performed the imitative act	Attending/Motivational
Mirror Imitation	Performing the act in the ispilateral area	Using the left hand when the demonstrator used their right hand	Self-Other Mapping Theory/Mirror Neuron Theory
Noncompliance	Performing a behavior that inhibits the child's ability to correctly perform the imitative act	Throwing objects on the table across the room	Behavioral deficits lead to an inability to perform imitative tasks
No-response	Failing to respond to the demonstrator	Remaining silent and seated in chair and failing to perform imitative task	Attending/Motivational theories

Table 2

Participant Characteristics (N=31)

	Low-functioning (IQ<70)		High-functioning (IQ>70)		Typical	
	Age(yr)	IQ	Age(yr)	IQ	Age (yr)	IQ
Mean	6.81	45.86	6.73	91.89	6.76	108.96
SD	2.86	8.49	2.56	18.58	2.99	16.34
Range	3-12	29-63	3-10	73-130	3-12	80-141

Table 3

Grand Means for all Error by Task Combinations (N = 49)

Error	Grand Mean	Standard Error	Degrees of Freedom	t-value
Object Task				
Multiple Attempts	1.53	.26	48.00	5.94**
Spatial	.98	.16	48.00	6.08**
Attending	.37	.13	48.00	2.84**
Mirroring	1.12	.16	48.00	9.73**
Non-Compliance	.14	.06	48.00	2.45*
No-Response	.08	.05	48.00	1.66
Object-Facial Task				
Multiple Attempts	2.18	.36	48.00	6.00**
Spatial	.97	.19	47.68	5.10**
Attending	.41	.16	48.00	2.60*
Mirroring	.84	.13	46.31	6.67**
Non-Compliance	.18	.09	48.00	2.14*
No-Response	.06	.05	48.00	1.35
Facial Task				
Multiple Attempts	2.12	.27	48.00	7.73**
Spatial	---	---	---	---
Attending	.53	.18	48.00	2.87**
Mirroring	---	---	---	---
Non-Compliance	.18	.08	48.00	2.27*
No-Response	.63	.21	48.00	3.02**

Note. *p <.05, **p <.01

Table 4

Mean Differences between Children with ASD and Typically Developing Children in Number of Errors across Task Type

Error	Mean Difference	Standard Error	Degrees of Freedom	t-value
Object Task				
Multiple Attempts	1.63	.49	47.00	3.36**
Spatial	1.55	.25	47.00	6.17**
Attending	.49	.26	47.00	1.88
Mirroring	-.51	.23	47.00	-2.21*
Non-Compliance	.23	.12	47.00	1.92
No-Response	.13	.10	47.00	1.28
Object-Facial Task				
Multiple Attempts	2.40	.68	47.00	3.54**
Spatial	1.41	.35	47.21	4.09**
Attending	.56	.32	47.00	1.75
Mirroring	-.09	.27	45.80	-.35
Non-Compliance	.29	.17	47.00	1.66
No-Response	.10	.09	47.00	1.03
Facial Task				
Multiple Attempts	2.47	.47	45.54	5.36**
Spatial	---	---	---	---

Attending	.84	.37	47.00	2.28*
Mirroring	---	---	---	---
Non-Compliance	.11	.17	47.00	.68
No-Response	1.00	.41	47.00	2.28*

Note. *p <.05, **p <.01

Table 5

Relationship between Mean Number of Errors and Level of Functioning

Error	Mean Difference	Standard Error	Degrees of Freedom	t-value
		Object Task		
Spatial	-.02	.01	46.00	-3.40**
Mirroring	+.01	.01	46.00	2.08*
		Object- Facial Task		
Spatial	-.02	.01	44.90	-2.55*
		Facial Task		
Multiple Attempts	-.04	.02	46.00	-2.29*
Attending	-.04	.02	46.00	-2.63*
Non-Compliance	-.02	.01	46.00	-2.49*
No-Response	-.05	.02	46.00	-3.00**

Note. *p <.05, **p <.01

Figure 1

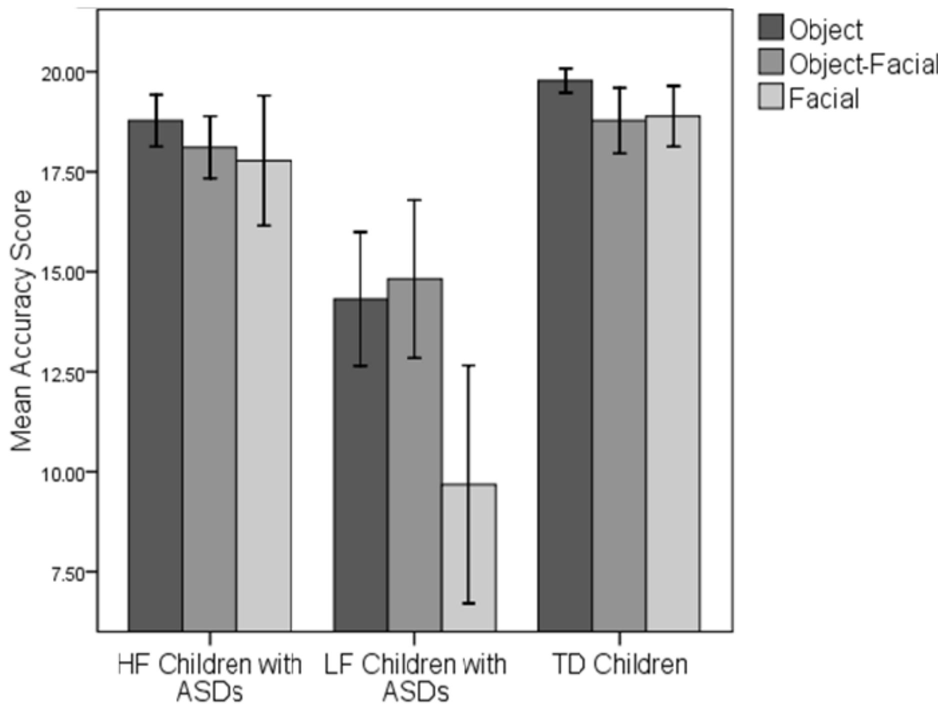


Figure 1: *Mean Accuracy Scores for Complete Imitation Battery and Composite Task Types by Group Membership.*

Note. LF(Low-functioning) children with ASD (N = 22), (HF) High-functioning children with ASD (N = 9), Typically Developing children (N = 18).

Figure 2

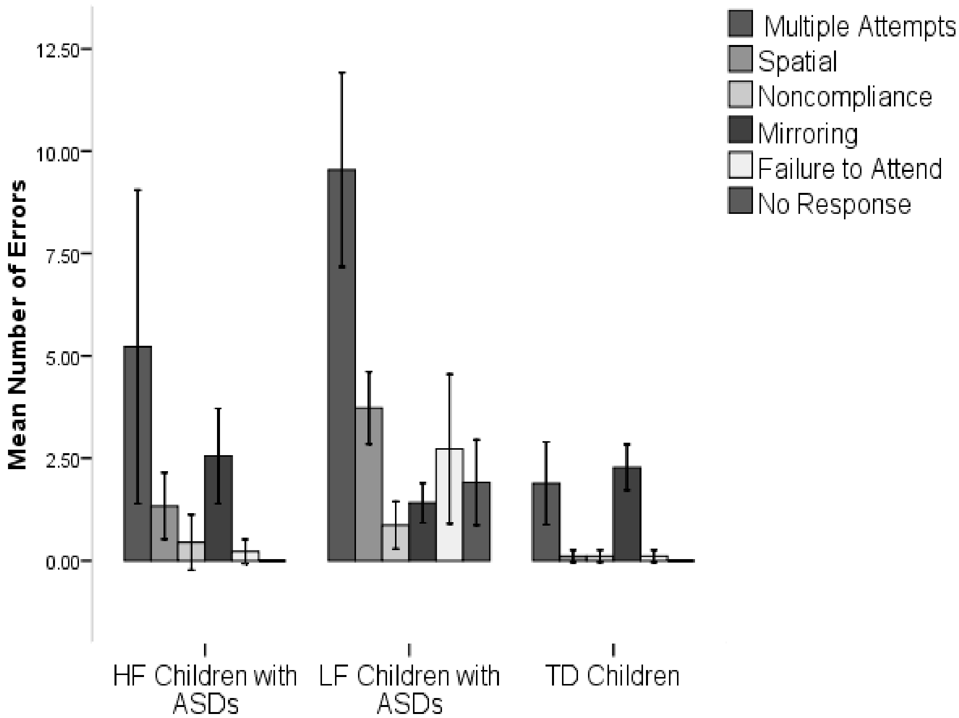


Figure 2. *Mean Errors Emitted for Complete Imitation Battery by Group Membership*.

Note. LF(Low-functioning) children with ASD (N = 22), (HF) High-functioning children with ASD (N = 9), Typically Developing children (N = 18).