Efficacy of Explicit Instruction to Teach Novel Morphological Forms to Children with Autism

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Abstract

Purpose: Many children with Autism Spectrum Disorder (ASD) present with morphosyntactic impairment. This study compared outcomes of implicit and explicit language interventions for children with ASD.

Method: Nineteen children with ASD and twelve typically-developing children completed one implicit-only and one explicit-added task targeting acquisition of novel verb inflections. Participants completed assessments measuring language, nonverbal IQ, and executive functioning.

Results: Statistical analyses showed no significant differences in mastery of novel verb inflections between implicit-only and explicit-added instructional conditions for either group. TD participants showed higher rates of mastery than ASD participants. There were no significant interactions between language ability, nonverbal IQ, or executive function.

Conclusion: ASD participants had more difficulty acquiring novel grammatical forms than TD peers, given either implicit-only or explicit-added instruction. ASD participants performed more accurately when given explicit rather than implicit-only instruction, but instructional condition was not correlated with mastery of the target form.

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Introduction

It has long been believed that children with Autism Spectrum Disorder (ASD) may learn differently than their neurotypical peers, with distinct strengths and weaknesses. Some research has also shown differences in the language profiles of children with ASD and those of children with developmental language disorder (DLD), with children with ASD showing increased difficulty in receptive language and children with DLD showing increased deficits in expressive language (Özyurt & Eliküçük, 2018). However, current research studies show parallels between the morphosyntactic profiles of children with ASD and those of otherwise typically developing children with DLD. For example, Huang & Finestack (2020) found that the majority of morphosyntactic features assessed did not significantly differ between children with ASD and those with DLD.

Prior research has shown that children with DLD have greater success learning morphosyntax when provided with explicit, deductive instruction in contrast to implicit, inductive approaches often used in academic and therapy settings (e.g., Stuckey, 2009). Explicit teaching methods provide the child with direct instruction. For example, a clinician may provide a child the morphological "rule" required to produce a given form (e.g., explicit instruction related to regular past tense *–ed* could involve providing the explanation that when we talk about actions in the past, we add *–ed* to the verb. Implicit teaching methods rely on modeling and include common clinical strategies such as recasting and expansion that do not attempt to make the child consciously aware of the underlying language rules. This latter approach requires the child to determine the rule on their own based upon repeated adult models of the targeted form (e.g., recasting a child saying "He walk to store" to "Yes, he walkED to the store." [*capitalized morpheme is* *produced emphatically*]). Explicit teaching strategies have been shown to be more effective and generalize more easily than implicit instruction for children with DLD (Finestack & Fey, 2009; Finestack, 2018). Although research has shown parallels between the language profiles of children with ASD and those with DLD with regard to morphosyntax, comparatively little research has investigated whether deductive teaching methods, involving explicit instruction, may also be an effective mode of intervention for children with ASD.

Research on the psycholinguistic processes responsible for the acquisition of morphological forms and rules has a long history. Jean Berko Gleason (Berko Gleason, 1958) devised the Wug Test, an assessment in which sentences containing nonsense words are used to elicit information about the ways in which children apply and generalize English-language grammatical forms, including plurals, verb tenses, and comparative morphemes (e.g., *-er, -est*). Berko Gleason's research demonstrated that children with typical language development have the ability to unconsciously learn morphological forms in the absence of direct instruction in their use and then apply those forms spontaneously to novel (or nonsense) words, proving that children do not merely memorize the forms for each individual word to which they are exposed. Although children with typical language development are able to acquire most or all grammatical markers in the absence of direct instruction in their use, there is a lack of consensus among clinical professions and researchers regarding whether children with language delays or disorders need, or benefit from, a more direct form of morphological instruction.

Given the limited research currently available on the efficacy of explicit instructional approaches for children with ASD, this study aims to explore whether, when given novel bound morphemes not present in English, children with ASD have greater success when provided with direct instruction than when provided with implicit instructional approaches. This research builds upon prior research conducted by Finestack and others (Bangert et al., 2019; Finestack, 2018; Finestack & Fey, 2009; McCabe & Finestack, 2020), as it uses a similar language learning task with novel grammatical targets with a yet unstudied demographic. Determining whether explicit instruction proves beneficial will have positive clinical implications for language intervention for children with ASD.

Autism and Language Disorders

In the *Diagnostic and Statistical Manual of Mental Disorders, 4th ed.* (DSM-IV; American Psychiatric Associate [APA], 1994) a diagnosis of ASD included meeting the criterion of "qualitative deficits in communication," defined by the presence of speech-language impairment or delays, as well as a lack of pretend or social-imitative play. At the time, Asperger's Disorder existed as a separate diagnosis in which other features of autism were present, but language development was typical. In the *Diagnostic and Statistical Manual of Mental Disorders, 5th ed.* (DSM-V; American Psychiatric Associate [APA], 2013), all diagnoses under the "pervasive developmental disorder" category (PDD), which include both autism and Asperger's, are collapsed into a single diagnosis of Autism Spectrum Disorder requiring "deficits in social-communication" but not specifically the presence of a delay or impairment in language development.

Despite this change in the DSM, there is evidence that a significant proportion of children with ASD experience weaknesses in their language development. Research indicates that 30% of children with ASD demonstrate little to no spoken language, defined by the expressive use of only 0-30 spoken words (Tager-Flusberg & Kasari, 2013) and of those who do use spoken language, a subset present with typical language skills and a subset present with language impairment (Tager-Flusberg & Joseph, 2003). Estimates of the relative size of these subsets vary widely based on variations in assessment measures and criteria used to define the presence or absence of language impairment. It remains unclear whether language impairments in autism are the result of comorbid language impairment or are the result of separate processes unique to autism (Riches et al., 2010; Tuller et al., 2017; Williams et al., 2008; Wittke et al., 2017).

The language abilities of children with ASD vary, but multiple studies indicate patterns of decreased use of specific morphological markers in children with ASD who have language impairments, including the past tense *-ed* and present tense *-s* verb endings (Bartolucci et al., 1980; Eigsti et al., 2007; Roberts et al., 2004; Tager-Flusberg, 1989). Wittke et al. (2017) identified the presence of four distinct cognitive-linguistic profile "groups" within a sample of 82, 5-year-old children with ASD taken from a larger, longitudinal study. These groups included those who presented with: (1) typical language development, including age-typical use of morphology (n = 21); (2) little to no spoken language use at 5 years of age (n = 29); (3) typical vocabulary development and nonverbal IQ scores but significant impairments in the use of grammatical language, including decreased use of morphological markers (n = 17); and (4) spoken language with deficits in both vocabulary and grammar and lower scores on nonverbal IQ tests (n =

13). They found that those with broader language impairments used morphological endings less frequently than those with typical language but tended to use them correctly when produced. In contrast, those with impairments in grammatical language, but not vocabulary, demonstrated the use of incorrect/unconjugated forms, as well as overgeneralization of related morphological bound morphemes. Their study, consistent with the findings of others, indicated that those children with ASD who present with significant morphological errors and decreased use of grammatical language demonstrate similar language profiles to those of children with a diagnosis of DLD or specific language impairment (SLI) (Dunn et al., 1996; Durrleman & Zufferey, 2009; Eisenberg & Guo, 2013; Huang & Finestack, 2020; Kjelgaard & Tager-Flusberg, 2001; Rice et al., 2004; Roberts et al., 2004).

Implicit vs. Explicit Approaches to Teach Morphology

Prior research has examined the efficacy of approaches that include explicit instruction compared to approaches that rely only on implicit methods to teach novel grammatical forms to children with and without language impairments. Ebbels (2014) reviewed the efficacy of implicit versus explicit interventions to support grammatical learning in school-age children with expressive language disorders. Results of the studies reviewed were inconsistent, which may be due to differences in population (e.g., age of the participants), the specific language forms selected, and the overall design of the studies. For example, Swisher et al. (1995) found that 4- to 6-year-old children with specific language impairment were better able to generalize novel-bound morphemes trained within the context of a story when provided with implicit-based rather than explicit-based instruction. In contrast, Finestack and Fey (2009) found that children aged

6 to 8 years with DLD better learned novel verb inflections when provided with an explicit-based rather than implicit-based instruction. Similarly, Finestack (2014) found that 3- to 7-year-old children with typical language development more successfully learned novel bound morphemes when given combined explicit-implicit instruction relative to implicit instruction alone. Finestack (2018) also found explicit-based instruction more effective for 5- to 8-year-old children with DLD.

Evidence of an advantage of explicit instruction over implicit for children with ASD with co-occurring language impairment is also beginning to emerge. For example, in a study of 17 children with ASD, aged 4 to 10 years, Bangert et al. (2019) found that children made significantly greater gains in application of a novel grammatical marker related to gender when given explicit-implicit combined instruction compared to implicit-only instruction. However, it is important to note that there was no difference in performance for the novel person grammatical marker, indicating that the benefits of explicit instruction may vary in significance according to the specific grammatical form being targeted.

In another study, Finestack et al., (2019) utilized a single-subject, noncurrent multiple baseline design to assess the efficacy of combined explicit-implicit instruction for children with weaknesses in their grammatical language use and characteristics of autism spectrum disorders. Target forms were selected for each individual participant based on their performance on administered speech-language assessments. Baseline data of production of target forms was collected for each participant. Participants then received five sessions of implicit-only intervention, with data collected during each session, followed by a minimum of five sessions of combined explicit-implicit instruction. All three participants maintained low rates of accuracy (i.e., 0% - 20%) across baseline and implicit-only intervention sessions. When provided with combined explicit-implicit intervention, all made significant gains in accuracy within three sessions. All participants achieved mastery criteria of a mean accuracy of 80% or above across three sessions within 5-17 combined explicit-implicit intervention sessions, and 2/3 participants maintained these gains two months after treatment had ended. Thus, it appears that explicit-implicit combined instruction may have advantages over implicit-only instruction when teaching morphosyntactic forms to children with ASD, though these advantages may not apply to all grammatical forms.

Proposed Models of Language Development for Children with ASD

The dual-systems model of language development (Ullman, 2001; 2004) may help to account for why children with ASD may benefit more from explicit instructional approaches than implicit approaches alone. Ullman (2001; 2004) posited that language development is characterized by two distinct systems, an explicit/declarative system consisting of lexical and semantic knowledge and an implicit/non-declarative system consisting of phonological and morphosyntactic knowledge. Following this, Ullman hypothesized that the specific profile of language impairment in children with ASD is the result of impairment to the non-declarative system only, impacting phonological and morphosyntactic knowledge and learning while leaving lexical and semantic knowledge largely unaffected (Walenski, Mostofsky, Gidley-Larson, & Ullman, 2008; Walenski, Mostofsky, & Ullman, 2014; Walenski, Tager-Flusberg, & Ullman, 2006). Under this model, then, it may be predicted that children with ASD demonstrate impairments in morphosyntactic use in excess of those that would be expected based on their overall language level. Additionally, if correct, Ullman's model could justify a hypothesis that children with ASD would demonstrate greater language gains when exposed to explicit instructional approaches, which are processed via the declarative system, than when exposed to implicit approaches, which rely on the non-declarative system.

The four-systems model of language acquisition (Boucher & Anns, 2018) is an alternative model aimed to account for weaknesses in language development experienced by individuals with ASD. According to this model, the language development of children diagnosed with autism is characterized by strengths in semantic memory (i.e., recall of learned facts and concepts unassociated with personal experiences) and procedural memory (i.e., recall of the steps and processes needed to perform particular actions), which they use to compensate for weaknesses in episodic memory (i.e., recall of one's own specific past experiences and events in one's own life) and relational memory (i.e., recall of information that is arbitrarily linked, as well as the ability to recognize ways in which information is related to other stored information and retrieve segments of related information together as a "set" or "group"). Additionally, the model accounts for differences in category formulation between children with and without ASD and theorizes that these differences are a result of differences in sensory-perceptual skills. Boucher and Anns cited earlier research indicating that individuals with autism demonstrate enhanced discrimination skills but impaired generalization abilities (Davis and Plaisted-Grant, 2014; Pellicano & Burr, 2012; Plaisted, O'Riordan & Baron-Cohen, 1998).

Morphosyntactic interventions utilizing exclusively implicit instruction rely on episodic memory (e.g., the ability to recall past examples in which particular forms were used) as well as relational memory (e.g., the ability to recognize relationships between different words utilizing shared morphosyntactic forms and the contexts in which these word forms occurred, as well as to retrieve this information as a unit in order to apply it to novel contexts). As noted, both of these memory processes are frequently impaired in children with ASD. In contrast, explicit morphosyntactic interventions are mediated through semantic memory (e.g., the ability to memorize linguistic "rules" for the application of particular morphological forms) as well as procedural memory (e.g., the ability to remember the steps for applying these forms correctly following opportunities for practice), which are areas of strength for this population. Thus, these models may yield support for the hypothesis that children with ASD will benefit more from interventions incorporating explicit instruction in combination with implicit instruction rather than those utilizing implicit instruction alone.

Memory & Executive Functioning in Children with ASD

Consistent with evidence supporting the four-systems model of language acquisition, Maister et al. (2013) identified a profile of children with ASD characterized by weaknesses in episodic and relational memory with intact performance in areas requiring item-based, declarative memory, a profile not found in their typically-developing, age-matched control group. Their study measured the ability of these children to recall and express autobiographical information in the context of personal narratives about specific past events, as well as their ability to memorize lists of both semantically-related and semantically-unrelated words. They found that children with ASD recalled more general autobiographical details but less episodic autobiographical information that was spatiotemporally linked to specific past memories than typically developing controls. Additionally, children with ASD recalled more items from a previously presented list of unrelated words than typically developing controls but recalled fewer items from a list that was organized into sets of semantically-related words.

The results of this research indicated that the ability of the children with ASD to recall specific factual information or memorized lexical items, which require semantic memory, exceeded that of their typically-developing peers. In contrast, their performance on measures requiring them to access relational memory processes to recall semantically- or spatiotemporally-linked information was significantly reduced relative to the performance of the typically-developing participants. Additionally, they found that the executive functioning abilities of children with ASD were correlated with relational memory, but not with item-based memory and, most significantly, that this correlation did not occur among typically-developing children. They concluded that, unlike typically-developing children who recall this information automatically, children with ASD rely on effortful strategies requiring the employment of executive functions to access relational information. Thus, children with ASD whose executive functioning is most impaired are also most likely to struggle with tasks that require relational memory.

Relational memory may also play an important role in the acquisition of morphosyntactic patterns in typical language development. According to the Relational Morphology Theory (Jackendoff & Audring, 2018; 2020), the acquisition of morphology is mediated through the ability to remember a stored set of lexical items and recognize the relationships between them, then generalize those patterns to novel lexical items sharing particular features. Thus, they argue that morphology is not simply the memorization and application of a "rule," but the creation of a *schema* that includes relationships between previously-encountered words and their various derivational forms. If this is the case, relational memory would serve as a primary mechanism through which morphosyntactic knowledge is gained and applied.

If typically-developing children are acquiring morphological forms implicitly via relational memory, an area of noted weakness in many children with ASD (Boucher and Anns, 2018; Walenski, Mostofsky, Gidley-Larson, & Ullman, 2008; Walenski, Mostofsky, & Ullman, 2014; Walenski, Tager-Flusberg, & Ullman, 2006), then it is likely that children with ASD are heavily relying on executive functioning abilities to recall and apply morphosyntactic patterns. By extension, children with ASD who exhibit impaired executive functioning abilities (due either to comorbid ADHD or autism-related challenges) would be expected to demonstrate increased difficulty acquiring morphosyntactic forms. Research indicates that executive functioning deficits are prevalent, but not universal, in autism, and that the presence and type of executive functioning impairments in individuals with ASD vary (Demetriou, DeMayo, M. & Guastella, 2019). Estimates of the prevalence of executive functioning deficits in individuals with autism have ranged from 30 to 70% (Geurts, Sinzig, Booth, & Happé, 2014; Pellicano, 2010). This may explain why some children with ASD show greater impairment than others in morphosyntactic development. Additionally, it is possible that teaching these forms and the rules for using them explicitly could not only circumvent the reliance on relational memory but shift that reliance to the child's generally more robust declarative memory faculties, thus reducing the executive functioning demands required for children with ASD to utilize correct morphological forms.

Metalinguistic Awareness

Rather than relying on episodic or relational memory systems necessary for implicit learning, explicit instructional approaches may be mediated through declarative memory, which likely requires a high level of metalinguistic awareness. In order to learn forms explicitly and apply them intentionally in rule-based ways, children require metalinguistic skills, defined as "an ability to think overtly about language and separate language form from meaning" (Chaney, 1992). Metalinguistic awareness includes the ability to understand that, at all levels, language is not a series of arbitrary sounds grouped together but instead that there are complex rules that govern how a language is written and spoken. For example, if an English-speaking child could apply a known "rule," such as adding an *-s* to pluralize regular nouns, they would know that, for example, you could have one "yammer" and six "yammers"; a child who lacked metalinguistic awareness and only knew whole words would very likely not be able to produce the latter form.

The majority of research on metalinguistic awareness has focused on two distinct areas: language development by individuals who are learning a second language (e.g., see Jessner, 2008) and development of reading skills (e.g., see Nagy & Anderson, 1995). However, a few studies have examined the metalinguistic awareness skills of children developing typically. For example, in an early study, Smith and Tager-Flusberg (1982) found that preschool-aged typically-developing monolingual children demonstrated awareness of metalinguistic concepts and that their metalinguistic knowledge was correlated with their overall language abilities. In contrast to these findings, McCabe (2020) found that metalinguistic awareness was not correlated with higher performance on tasks measuring morphosyntactic skills in typically-developing 3- to 10-year-old children. These opposing findings may be due to differences in the ages of the children included or the metalinguistic and language tasks used.

It is possible, however, that even if typically-developing children rely primarily on non-metalinguistic mechanisms for acquiring morphosyntactic patterns (or, at the very least, do not solely rely on metalinguistic awareness for morphosyntactic acquisition), this pattern may not hold true for children with ASD. If typically-developing children acquire their understanding and use of morphology by relying on episodic and relational memory (i.e., remembering previous examples of morpheme application and implicitly applying those patterns to novel contexts), then high levels of metalinguistic awareness may not be necessary for their use of derivational morphology. In contrast, if children with ASD demonstrate weaknesses in episodic and relational memory, then strong metalinguistic awareness may allow them to bypass these potentially more "traditional" channels of morphosyntactic learning and application.

Moreover, it may be the case that children with ASD have relatively strong metalinguistic skills despite weaknesses in executive functions. Palm (2017) found that metalinguistic awareness levels did not differ between children with a diagnosis of attention deficit hyperactivity disorder (ADHD) and typically developing controls. As ADHD is defined in large part based on the presence of deficits in executive functioning, Palm concluded that these results may indicate that metalinguistic awareness and executive functioning exist as distinct processes that are not correlated with or dependent on one another. Given this, children with ASD with decreased executive functioning skills (who cannot rely on the use of effortful executive functioning strategies to compensate for relational memory deficits) may nonetheless be able to attain high levels of metalinguistic awareness and use these skills to compensate when acquiring and using morphological forms.

Formal investigations of the metalinguistic awareness skills of children with ASD are still nascent. However, a longitudinal study by Huang et al. (2019) found that metalinguistic skills did not differ substantially between children with ASD and their typically developing peers on most measures, with the exception that children with ASD demonstrated significantly greater gains over a 1-year period on two measures of metalinguistic awareness: the Word Swap task and the Morpheme Production task (see *Method* section, *Metalinguistic Awareness Probe*, for a thorough explanation of these tasks).The results of this study indicate that children with ASD may have equal or greater metalinguistic skills relative to their typically-developing peers. As executive functioning skills are often impaired for children with ASD, this appears to be consistent with Palm's (2017) findings that metalinguistic awareness and executive functioning exist as distinct processes. This is also consistent with the most recent researchwhich has shown that metalinguistic awareness is often less impaired in children with ASD than other language abilities, as it builds upon their cognitive strengths in both procedural and semantic memory (Boucher & Anns, 2018; Pellicano & Burr, 2012

Current Study

Although there is some initial research investigating the efficacy of morphological language interventions for children with autism diagnoses and language weaknesses, there remains limited evidence regarding whether morphological instruction for this population of children is more efficacious when delivered explicitly with deductive, explicit teaching methods or implicitly via inductive teaching methods. Thus, the aims of the current study were to address the following research questions:

1. Are 5- to 8-year-old children with ASD more likely to learn a novel grammatical form when taught using an implicit-only or explicit-implicit combined instructional approach?
2. Are there differences in the learning of novel grammatical forms with implicit-only and explicit-added instruction between age- and language-matched children with ASD and those developing typically?
3. Do participant characteristics such as language and cognitive ability, executive function skills, metalinguistic abilities, parent-reported gender, and age, account for differences in task performance across these groups of children?

Based upon prior research of the language and cognitive strengths and challenges of children with ASD, it was predicted that participants with autism would have greater success when provided with explicit-implicit combined, rather than implicit-only instruction. Because of relation previously identified between executive functioning and learning abilities and an ASD profile associated with weak executive functioning skills, it was predicted that the typically-developing children would have greater success learning the novel-bound morphemes (in the context of the single session teaching opportunity utilized in this study) relative to the children with ASD. It was also predicted that expressive language and metalinguistic awareness would be strongly associated with successful acquisition of novel-bound morphological forms.

Method

Data collection for all participants occurred between December 2019 and March 2020 at the University of Minnesota. Participants were recruited from the metropolitan Minneapolis-St. Paul area through the University of Minnesota's Focus in Neurodevelopment (FiND) registry as well as through flyers placed in local speech, language, and hearing clinics and autism centers and social media advertisements.

The study's protocol was completed in conjunction with Bangert's study (2020) examining the relationship between heart rate variability and participation in cognitive and social activities, as well as Huang's study (2020) examining comprehension of indirect answers and determination of speaker intention. The study was approved by the University of Minnesota's Institutional Review Board for human subjects. Parents of all participants signed consent forms prior to initiation of study activities. Children participating in the study also gave oral consent and signed an assent form. Families were compensated $60 in exchange for their children's participation in the study.

Participants

This study included 31 children between the ages of 5 and 8 years. Of these, 19 were diagnosed with autism spectrum disorder (ASD) and 12 were typically-developing. As none of the children were asked to self-identify their own gender, gender is based on parent report; anyone reported as "female" will henceforth be referred to as AFAB (Assigned Female at Birth) and anyone reported as "male" as AMAB (Assigned Male at Birth). The ASD group included 6 AFAB and 13 AMAB participants, and the TD group included 3 AFAB and 6 AMAB participants. Parent education and household income levels were reasonably well-matched for the two groups. Additionally, the children in the two groups were well-matched for gender distribution (*p* = 0.90), based upon parent report, but slightly less well-matched for age (*p* = 0.13). See Table 1 for a description of all relevant participant characteristics.

To be eligible for this study, children in the TD group needed to be between the ages of 5 and 8 years and native English speakers with no developmental history of ASD. Initial screening during recruitment were completed to rule out hearing loss and any other significant developmental delays or disorders, based on parent report. Children in the ASD group also needed to be between the ages of 5 and 8 years and native English speakers. During the screening and recruitment stage parents were asked to confirm that their children had a diagnosis of ASD and provide details of diagnosis. All children in both groups needed to be verbal and using at least 4-word utterances.

Table 1

Participant Characteristics

		Group		
Characteristic		**ASD** (*n* = 19)	**TD** (*n* = 12)	***p*-value** (*t-test Comparison*)
Age (Years)				
	Mean	7.50	6.91	0.13
	SD	1.06	1.11	
	Min-Max	5.34 - 8.92	5.09 - 8.51	
Parent-Reported Gender				
	AMAB:AFAB	13:6	6:3	0.90
Parent Education (Years)				
	Mean	17.05	16.75	0.35
	SD	1.93	2.45	
	Min-Max	12 – 20	12 – 20	

Household Income (Annual)			
$0-$25,000	1	0	0.80
$25,001-$50,000	2	2	
$50,001-$100,000	5	5	
$100,001-$150,000	7	3	
$150,001 or greater	4	2	

Procedure

Information was collected from parents related to race, parent education, and current income levels. Additionally, for children diagnosed with autism, further information was collected regarding age of diagnosis and any therapeutic services (occupational therapy, physical therapy, reading, writing, speech language therapy) their child was receiving. Parents of the children in both the ASD and TD groups also completed the Behavior Rating Inventory of Executive Function (BRIEF; Gioia, et al., 2000) as a parent-reported measure of executive functioning across social contexts.

Parent Assessments

Behavioral Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000)

This parent-completed inventory assesses executive functioning of children aged 5 to 8 years using a 3-point Likert scale, with 1 as “not usually,” 2 as “sometimes,” and 3 as “often.” The questions correspond to eight clinical scales measuring the following domains: inhibit (exercising impulse control), shift (transitioning between tasks and task components), emotional control (regulation and patterns of emotional responses), initiate (beginning a task), working memory (holding information actively in one’s mind for the purpose of task completion), plan/organize (use of strategies to prepare for tasks in advance), organization of materials (the ability to keep things in order within one's physical space), and monitor (assessing and reflecting on one's own performance).The test also provides a Global Executive Composite score, which is calculated using the results of the subscales. On this measure, higher raw and T-scores indicate increased levels of impairment in executive functioning; Global Executive Composite T-scores above 59 are considered to indicate deficits in executive functioning.

Child Standardized Assessments

The children in the ASD group completed the Autism Diagnostic Observation Schedule, Second Edition (ADOS-2; Lord et al., 2012) to confirm study eligibility and to index ASD symptom severity. The ADOS-2 was administered by a PhD graduate student (SLP-CCC) with specific certification and training in administering this assessment. All other assessments were administered in a randomly selected order by one of three trained graduate students.

Children in both the ASD and TD groups completed portions of three standardized assessments: four subtests of the Clinical Evaluation of Language Fundamentals, 4th Edition (CELF-4), the Pragmatic Language subtest of the Comprehensive Assessment of Spoken Language, 2nd Edition (CASL-2), and the Matrices (nonverbal intelligence) subtest of the Kaufman Brief Intelligence Test, 2nd Edition (KBIT-2). In addition to individual standardized scores for each subtest of the CELF-4, a combinational score was calculated to compare overall language abilities for each child (Core Language Index (CLS)). Each child also completed a three-part formal, non-standardized assessment of metalinguistic abilities. Table 2 contains descriptive of each study group's performance on each of these measures as well as cross-group *t*-test comparisons for each assessment.

Autism Diagnostic Observation Schedule, Second Edition (ADOS-2; Lord et al., 2012)

All participants whose parents indicated a previous diagnosis of ASD completed the ADOS-2 prior to participating in other study activities. The ADOS is a standardized assessment that consists of both structured and semi-structured tasks that involve social interaction with the examiner. It is designed to measure social-communication and the presence of restricted and repetitive behaviors associated with a diagnosis of ASD. This measure provides scores for the domains of "social affection" and "restricted and repetitive behaviors" as well as an "overall total" score. An Overall Total score of 7 or higher is considered indicative of Autism Spectrum Disorder while a score of 9 or higher falls into the more specific diagnosis of Autism. For this study, eligibility for inclusion in the ASD group of participants required scores greater than or equal to 7 on this measure. This Overall Total score is then converted to a Comparison Score to determine relative level of ASD symptom severity, with a score of 1 corresponding to minimal-to-low symptom severity and a score of 10 corresponding to high symptom severity.

Clinical Evaluation of Language Fundamentals, Fourth Edition (CELF-4; Wiig, Semel & Secord, 2004) Subtests of: Following Directions, Word Structure, Recalling Sentences, and Formulated Sentences

The CELF-4 is a norm-referenced, standardized assessment for children and adults, 5 to 21 years old. Individual subtests may be administered and scored separately, or the entire battery may be given, addressing expressive, receptive, and pragmatic language abilities. For this study, participants completed four subtests of this assessment, three which evaluated expressive language skills (Word Structure, Recalling Sentences, and Formulated Sentences) and one which evaluated receptive language only (Following Directions). No time limits were given and repetitions were allowed as directed in the assessment manual. For each subtest, one to three unscored trials are given to provide examples of anticipated responses.

The Word Structure subtest requires the child to provide the correct morphosyntactic form for each fill-in-the-blank sentence read by the administrator. An example sentence is read to clarify the expected morphosyntactic form while the administrator points to simple color images that correspond to each sentence. For example, the child is shown a picture of one boy standing and one boy sitting. The administrator then says the following: "This boy *[points]* is standing and this boy is...*[point and pause]"*. The child is expected to produce the form "sitting" to parallel the first sentence. Repetitions are allowed and there is no ceiling for this subtest (i.e., the child must complete all items regardless of ability).

The Recalling Sentences subtest assesses receptive, expressive, and working memory abilities. For this subtest the child is expected to listen to the administrator read a sentence aloud and then repeat the sentence verbatim. The examiner scores the child's response relative to the number of errors the child made (3 = 0 errors, 2 = 1 error, 1 = 2-3 errors, and 0 = > 4 errors), with some dialectical variation allowed. Repetitions are not allowed and administration of the subtest is discontinued after four consecutive scores of zero.

The Formulated Sentences subtest assesses a child's ability to produce grammatically correct, logical sentences of increasing complexity given contextual constraints. For each item the administrator presents a picture and provides the child with a single word that must be included in the sentence they produce. The child must use the given word, without changing plurality (noun) or tense (verb), and the sentence must be logical for the image given. The examiner scores the child's response on a scale from 0 to 2 (2 = complete, grammatical, and contextually logical sentence including the target word in its unaltered form; 1 = complete and contextually logical sentence that has one or two errors; 0 = more than two errors, omission of the target word or change of its form, or creation of a sentence that includes the target word but is not about the given image). Repetitions are allowed and administration of this subtest is discontinued after four consecutive zeros.

The Following Directions subtest assesses the child's ability to follow specific directions of increasing complexity, relying on receptive language and procedural memory skills. To be able to successfully complete items on this subtest the child must also understand descriptive terms such as number, relative size and color, as well as temporal markers and locatives. For example, the child may be presented with a line of multiple shapes of varying sizes and colors (e.g., circles, squares, and triangles) and then asked to "point to the big black circle and the small white circle." The "and" specifies that the child must point to the big black circle first and they must point to the correct size and color of shapes. The examiner assigns the child a score of 1 if they followed the directions exactly or a score of 0 if there are any errors. Repetitions are not allowed as this is broadly an assessment of listening comprehension and following directions, and the subtest is discontinued after four consecutive scores of 0.

Each subtest yields a standard score with a mean of 10 and standard deviation of 3. A composite score is derived from all four subtests, the Core Language score, which is a standard score with a mean of 100 and standard deviation of 15. These measures were used to characterize the participants' language abilities.

Comprehensive Assessment of Spoken Language, Second Edition—Pragmatic Judgement Subtest (CASL-2; Carrow-Woolfolk, 2017)

The CASL-2 is a norm-referenced, standardized assessment for children and adults, age 3 through 21 years of age. Similar to the CELF-4, the CASL-2 is a comprehensive battery of language abilities but with a specific focus on expressive language. For the current study, children only completed the pragmatic language subtest. This subtest consists of scenarios (both with and without related images) for which the administrator reads an example of an everyday life scenario and then asks a child how they would respond. Responses are open-ended, but children are expected to provide responses deemed appropriate for the scenario. For example, for the item, "Suppose the telephone rings. You pick it up. What do you say?" any variation of greeting would result in a score of 1 and any other answer would result in a score of 0. Some items require the child to provide multiple responses, such as steps in a process or items on a list; if they do not provide the requisite number, a single prompt of "Can you think of anymore?" is allowed. Standard basal and ceiling were used, with a basal of 1 on 3 consecutive items and a ceiling of 0 on 5 consecutive items. This subtest yields a standard score with a mean of 100 and standard deviation of 10. Performance on this subtest was used to characterize the participants' pragmatic language abilities.

Kaufman Brief Intelligence Test, Second Edition—Matrices Subtest (KBIT-2; Kaufman & Kaufman, 2004)

The KBIT-2 is a norm-reference, standardized assessment for children and adults, 4 to 90 years old. All participants completed the Matrices subtest, which is a measure of nonverbal intelligence. This subtest assesses an individual's problem-solving abilities by having them complete visual analogies. It is a test of nonverbal reasoning, as vocabulary and language skills are not necessary for comprehension and completion. Implementation of this subtest involves showing the child pictures or abstract shapes that follow a particular pattern or are related, and then asking the child to point to the image that completes the pattern. The Matrices subtest includes 46 items. Every child assessed for the purposes of this research reached a testing ceiling prior to completion of all items. The Matrices subtest yields a standard score with a mean of 100 and standard deviation of 10. Performance on this subtest was used to characterize the participants' nonverbal cognitive abilities.

Table 2

Group Aggregate Standardized Assessment Scores

		Group		
Assessment, Subtest/Index		**ASD** (n = 19)	**TD** (n = 12)	***p*-value**
ADOS Comparison Score *[Corresponding Symptom Severity]*[a]				
	Mean	6.63 *[Moderate]*	***	
	SD	1.92	***	
	Min-Max	4 [*Low*] - 10 [*High*]	***	

CELF-4 Recalling Sentences [b]			
Mean	8.37	12.08	
SD	4.35	3.59	
Min-Max	1 – 15	4 – 18	
CELF-4 Formulated Sentences [b]			
Mean	8.63	11.85	
SD	5.24	2.12	
Min-Max	1 – 16	8 – 16	
CELF-4 Core Language Index [c]			
Mean	88.68	108.54	
SD	22.36	12.75	0.006
Min-Max	44 -120	84 – 127	
CASL-2, Pragmatic Language Subtest [c]			
Mean	95.68	106.62	0.088
SD	21.44	17.24	
Min-Max	63 – 139	83 – 135	
KBIT-2, Matrices Subtest[c]			
Mean	105.16	107.23	
SD	20.34	12.57	0.969
Min-Max	69 – 137	83 – 127	
BRIEF, Global Executive Composite (T-Score)			
Mean	68.89	45.92	<0.0001
SD	10.62	7.7	
Min-Max	48 – 85	38 – 65	

[a]Administered to ASD participants only; [b]Standard Score with Mean = 10, SD = 3;
[b]Standard Score with Mean = 100, SD = 10

Metalinguistic Awareness Probe

The metalinguistic awareness probe was a three-part formal, non-standardized probe of metalinguistic skills, assessing metasemantic, metasyntactic, and metamorphological awareness. All sections of the probe were adapted from previous peer-reviewed studies of metalinguistic awareness (Berko Gleason, 1958; Bialystok, 1986; Chaney, 1992; Piaget, 1929;), and consisted of Word Swap (metasemantic), Morpheme Production (metasyntactic), and Grammatical Judgement (metamorphological) tasks. For each task, children were given verbal instruction, and/or viewed images on an iPad, and asked to provide verbal responses. There was no ceiling for responses, and children answered all items to the best of their ability or provided no response ("NR"). Overall percentage accuracy scores were calculated for each task by dividing the total number of items correct by the total number of items administered. Table 3 contains descriptions of each groups' performance on the three metalinguistic tasks as well as cross-group *t*-test comparisons for each assessment.

For the Word Swap task, the examiner asked the child to imagine a scenario in which words meant their opposite (e.g., "sun" and "moon" have switched denotative meaning) and then asked the child a question to assess comprehension of this hypothetical scenario. If the child did not provide the correct response to the example question, the examiner provided the correct answer. This section consisted of eight questions with two specific scenarios ("sun/moon" and "cat/dog"). For the sun/moon scenario the child would be asked a question such as: "What do you see when you wake up in the morning?", with the anticipated answer of "moon." Feedback was not provided as to whether or not the child answered correctly.

The Morpheme Production task was a slightly modified version of the well-known "Wug Test" (Berko Gleason, 1958). The task included 18 items that assessed metasyntactic skills involving novel nouns and verbs. This probe requires knowledge of regular plural -s, past tense, and present progressive forms, among others, to be able to answer correctly. When given a sentence containing the novel word and an image of more than one of something or someone doing an action, the child was expected to verbally complete the sentence with a contextually correct grammatical form as a response. For one item, the child is shown a picture of a person swinging an object and told that the person "knows how to RICK" and then must complete the sentence "Yesterday he _______". The child is expected to provide "*RICKED*" as a response, following the contextual clue of "yesterday" implying past tense and the regular English past tense bound morpheme, *–ed*.

The Grammatical Judgement task required the child to listen to an audio recording of someone saying a sentence such as "The trees are running" or "The man drive the car" and decide whether the sentence was grammatical (i.e., "something we could say if we wanted to" even if it was meaningless (i.e., "silly"). The task included 12 items: 3 grammatical and meaningful; 3 ungrammatical, but meaningful; 3 grammatical, but not meaningful; and 3 ungrammatical and not meaningful.

Table 3

Group Performance on Metalinguistic Tasks

Task, % Correct		Group: ASD (*n* = 19)	Group: TD (*n* = 12)	***p*-value**
Word Swap *(Metasemantic Tasks, 8 Items)*				
	Mean	57.35	71.15	
	SD	24.23	21.28	0.21
	Min-Max	0 - 100	50 - 100	
Morpheme Production *(Metasyntactic Tasks, 17 Items)*				
	Mean	56.08	73.31	
	SD	24.20	23.97	0.06
	Min-Max	23.52 - 94.12	5.88 - 100	
Grammatical Judgement *(Metamorphological Tasks, 12 Items)*				
	Mean	64.21	71.53	
	SD	17.62	16.84	0.76
	Min-Max	41.67 - 100	41.67 - 100	

Experimental Language Learning Task

Participants were randomized to one of four sequences. The sequence assignment determined the order of instructional tasks (i.e., implicit-only, explicit-added) and the targeted novel morpheme (i.e., person form; gender form). All sequences included both an implicit-only and an explicit-added task. The four possible sequences to which children were assigned included: Explicit-added with Person form/Implicit-only with Gender form; Implicit-only with Person form/Explicit-added with Gender form; Explicit-added with Gender form/Implicit-only with Person form; and Implicit-only with Gender form/Explicit-added with Person form. Novel grammatical morphemes were used for this task to help minimize the children's use of prior morphosyntactic knowledge to complete the task given that English does not have morphosyntactic verb markers for first person or gender. Each sequence was administered over the course of a single session; some participants completed both tasks in the sequence consecutively during one session, while others completed either the implicit-only or explicit-added task during one session and the remaining task during a separate session. Due to COVID-19-related challenges, seven participants with ASD and one TD participant completed only one task (implicit-only or explicit-added).

The novel morphological forms targeted in this task marked each clause's verb according to the person (i.e., 1^{st} person ("I") versus 2^{nd} person ("you")) or gender of the sentence subject using the same forms as previous studies (e.g., Finestack, 2018; McCabe & Finestack, 2020).

Regardless of the sequence, the examiner used an iPad to present the task, which began with introduction to one of two colorful creatures from outer space, named either "Lele" or "Wobo." Audio instructions recorded on the iPad told the child that the creature just came to earth and "talks a little bit differently." The child was told to listen closely so that they could learn to talk like the space creature. The space creature added a word-final /ʃ/ ("sh") or /f/ morpheme in order to mark either first-person ("I") or male subjects.

The assignment of these morphemes was counterbalanced such that the explicit-added person condition used /f/ to mark first-person subjects while the implicit-only person condition used /ʃ/, and the explicit-based gender condition used /ʃ/ to mark male subjects whereas the implicit-based gender condition used /f/. Each condition consisted of a two-part training segment (auditory discrimination and expressive responding with corrective feedback) and a final Receptive Judgement probe.

Training: Modeling

The training segment of each language learning task began with eight trials in which the space creature modeled use of the target form. Participants viewed drawings of children engaging in a variety of actions (e.g., reading, jumping). These children were depicted alone when gender morphemes were targeted and were depicted alongside the space creature when person morphemes were targeted. When the first-person “I” form was targeted, the space creature was depicted engaging in the targeted action with the child watching (see example, Figure 1). When the 2nd-person “you” form was targeted, the child was depicted engaging in the targeted action with the space creature watching. When gender was the target, participants simultaneously listened to audio recordings in which the space creature labeled what each child was doing in the image, using a consistent carrier phrase “[name] can [action]” (see example, Figure 2). The eight trials consisted of four in which the novel morpheme was applied (i.e., the person condition included four trials in which 1st-person subjects were indicated by applying a novel verb inflection; the gender condition included four trials in which a male subject was indicated by applying a novel verb inflection) and four in which the morpheme was *not* applied (i.e., in the person condition, four trials in which a 2nd-person subject was indicated by *not* applying the novel inflection; in the gender condition, four trials in which a female subject was indicated by *not* applying the novel inflection).

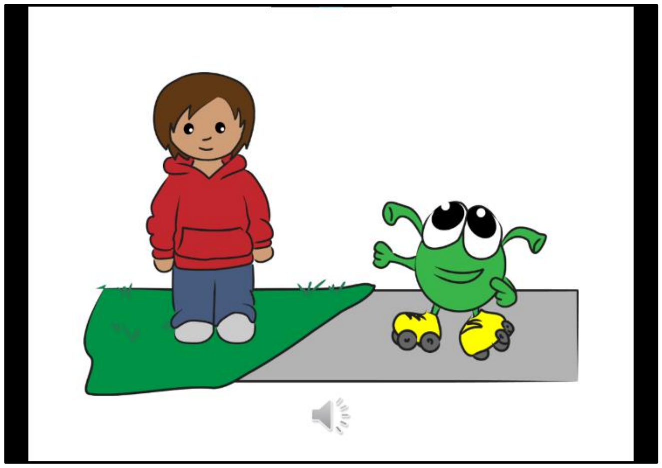


Figure 1 – *Image depicts an alien skating and a child standing. During study, simultaneous presentation of the audio "Now I skate-f"*

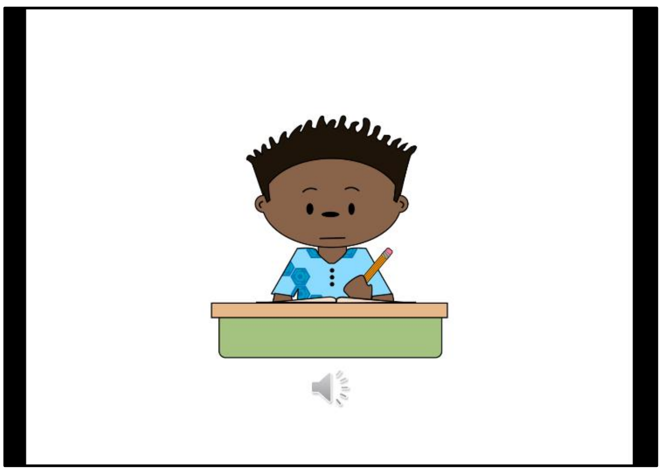


Figure 2 – *Image depicts a child sitting at a desk writing. During study, simultaneous presentation of the audio "Mike can write-sh"*

In the explicit-added condition, a recorded narration explicitly stated the rule for application of the novel verb inflections three times: prior to the first trial and following the 4th and 8th trials. The auditory instruction provided for the person morpheme was "When you talk about yourself, you add /f/ to the end. When you talk about someone else, you do not add anything to the end." The instruction for the gender morpheme was ""If it is a boy, you have to add /ʃ/ ("sh") to the end. If it is a girl, you do not add anything to the end." In the implicit-only condition, the rule was not stated. Instead, participants were given the instruction to "Listen closely so you can talk like [Lele/Wobo]" prior to the first trial and following the 4th and 8th trials.

Training: Expressive Responding with Corrective Feedback

The second part of the training segment also consisted of eight trials. The illustrations used in this portion were identical to those in the Modeling segment. However, instead of hearing the entire sentence with the novel target modeled, children were presented with cloze cues (i.e., auditory "fill-in-the-blank"-style sentence completion prompts). For example, a picture of a child with short hair running was paired with the cloze cue ("Jake can ___"). In both explicit-added and implicit-only conditions, participants were provided with feedback on whether their response was correct. For incorrect responses, participants heard, "Oops, that isn't how [Lele/Wobo] talks. Listen to [Lele/Wobo] again." Thus, all participants, regardless of their response accuracy, were provided with another model of the target form (e.g., "Jake can run-sh") following this feedback.

Just as in the auditory discrimination training segment, in the explicit-added condition, the rule for application of the verb inflections was presented prior to the 1st and following the 4th and 8th trials; in lieu of this, the instruction to "listen closely so you can talk like [Lele/Wobo]" was presented during implicit-only tasks at the same intervals. Correct responses consisted of application of a novel-bound morpheme for four of the eight presented trials; correct responses for the other four trials consisted of typical uninflected English-language verb forms.

Receptive Judgement Probe

The final segment of the language learning task was a probe in which participants had to identify the illustration that matched a single verb presented. This segment consisted of ten trials. A field of two pictures was presented on the iPad screen, with both pictures representing the same action performed by different subjects. A spoken recording of an inflected or uninflected verb representing the depicted action was played along with each presented set of 2 pictures. For example, one item included a picture of a child with long hair crying on the left and a picture of a child with short hair crying on the right, along with the auditory cue, "cry-sh" (see Figure 3).

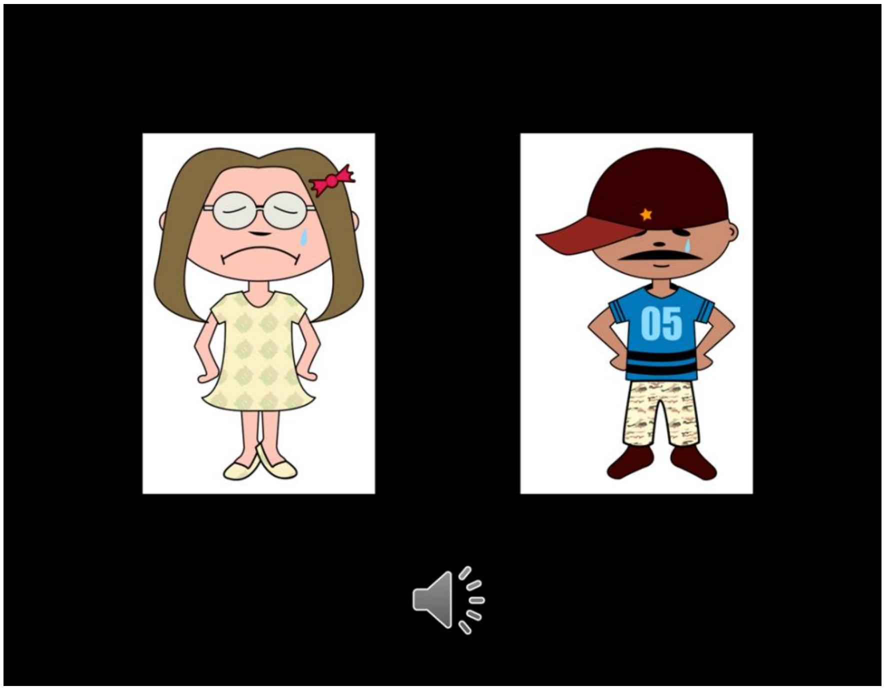


Figure 3 – *Image depicts two children standing next to each other with closed eyes and a tear on their cheek. During study, simultaneous presentation of the audio "cry-sh". Anticipated response is for the child*

Presented recordings included five verbs with novel inflections (i. e., word-final /ʃ/ ("sh") or /f/) and five uninflected verbs. The anticipated response from the child was that they would point to the image that corresponded to that verb form (i.e., the space creature or child completing an action in the person-form task, and a child with long hair or a child with short hair in the gender-form task). No feedback was provided to the participants regarding whether their responses were accurate during this Judgement probe.

Scoring and Data Entry

Assessments were administered, scored, and entered into a database by one of three trained research assistants, which included two Ph.D. students and one Masters-level student. A trained undergraduate student assisted with data entry and scoring for parent questionnaires only.

After administration of an assessment, both raw and standard scores were calculated by the research assistant who administered it. Following this, each assessment was then double scored by one of the three graduate-level research assistants who did not participate in the first round of scoring. If the first and second scorer were not in agreement, a third independent scorer was utilized to determine a final score.

Analyses

To address Study Questions 1 and 2, we employed nonparametric chi-square analyses. First, we characterized participants' performance for the implicit-only and explicit-added tasks as either Master or Non-Master. A cut-off of 80% correct on the Judgement Probe was used as the criterion. This criterion has been used in previous examinations using similar probes (Finestack, 2014, 2019; Finestack & Fey, 2009).

Study Question 1, focused on individual performance of children with ASD between implicit-only and explicated added conditions, It required a within-participant comparison of the ASD group's performance in the implicit-only and explicit-added conditions; thus, we used McNemar's test to compare Masters and Non-Masters in each condition (see Table 4). While this research question was focused on the performance of children in the ASD group, TD group performance was also calculated as a control-group comparison. Chi-square and related p-values were calculated independently for each group. Sample size for answering this research question was reduced, as 7 of the 19 participants in the ASD group and 1 of the 12 participants in the TD group did not complete both an implicit-only and an explicit-added condition (see Table 4 for participant distribution, *n*).

Study Question 2 asked if there was a difference in performance between the ASD and TD groups for each condition (implicit-only; explicit-added). It required between-participant comparisons of the ASD and TD groups' performance in each condition; thus, we conducted two separate Fisher's Exact Tests to address this question (see Tables 9 and 10 for the chi-square contingency table and statistical results, respectively.). All ASD and TD participants were included in this analysis in explicit-added and/or implicit-only conditions, as cross-condition performance at the individual level was not relevant (see Table 10 for participant distribution). For both sets of analyses, we estimated effect sizes using Phi (Φ), with Phi's of 0.10, 0.30, and 0.50 representing small, medium, and large effect sizes, respectively (Green & Salkind, 2003).

To address Study Question 3, which asked if whether specific participant characteristics (such as age, parent-reported gender, and baseline language abilities) impacted performance, we employed mixed-effects regression analyses. First, we examined how factors related to the language learning task (fixed effects), including task order, probe number, item order, target morpheme, and instruction type, predicted the binary outcome of success or failure on each trial of the Receptive Judgement Probe. Next, we examined how factors related to individual-differences, including participant age, diagnosis, language ability, nonverbal IQ, executive function, parent-reported gender, and performance on metalinguistic awareness probes, predicted task performance. Contrast coding was used for all binary variables and all continuous variables were z-scaled transformed. We used an iterative model-building procedure (i.e., stepwise, with forward selection) to complete the logit mixed-effects analyses. We fit the models using the lme4 package in R (Bates, Mächler, Bolker, & Walker, 2015). The assessment of the statistical significance of individual predictors within models was based on the lmerTest package (Kuznetsova, Brockhoff, & Christensen, 2013).

Results

Research Question 1: Comparison of Performance in Implicit-Only and Explicit-Added Instructional Conditions

While Research Question 1 is focused on the performance of children in the ASD group, TD group performance was also calculated as a control-group comparison. Related analyses compared performance on the implicit-only and explicit-added tasks within participants. For the ASD group, using a McNemar's chi-square test, a value of $\chi^2 = 0.250$ with 1 degree of freedom was calculated, resulting in a two-tailed p-value of 0.617; from this an effect size of $\Phi_{ASD} = 0.174$ was calculated. One participant met mastery in the Implicit-only condition and three met mastery in the explicit-added condition. For the TD group, an χ^2 value of 3.200 with 1 degree of freedom was calculated, resulting in a two-tailed p-value of 0.074; from this an effect size of $\Phi_{TD} = 0.289$ was calculated. Five participants met mastery levels in both instructional conditions and an additional five participants only met mastery in the explicit-added condition. Based upon these analyses alone, instructional condition did not appear to have a statically significant impact on performance, as both $p_{ASD} = 0.617$ and $p_{TD} = 0.074 > p = 0.050$. Additionally, effect size for both groups ($\Phi_{ASD} = 0.174$ and $\Phi_{TD} = 0.289$) is considered small, interpreted as a weak relationship between variables. See Tables 4 and 5 for the contingency table and related statistic values, respectively. Tables 6 and 7 contain individual scores for the ASD and TD participants, respectively. Table 8 includes the means and standard deviation of performance for ASD participants who completed both conditions.

Table 4

Chi-Square Contingency Table, McNemar's Test

		Implicit *(Control)*		
		Master (80%+)	Non-Master (< 80%)	TOTAL
	ASD Group (*n* = 12)			
	Master (80%+)	0	3	**3**
	Non-Master (< 80%)	1	8	**9**
Explicit (*Case)*	Total	**1**	**11**	***12***
	TD Group (*n* = 11)			
	Master (80%+)	5	5	**10**
	Non-Master (< 80%)	0	1	**1**
	Total	**5**	**6**	***11***

Table 5

Statistical Analysis of Intraparticipant Performance, Explicit-added/Implicit-only Conditions

	Group	
Statistical Test	**ASD** (*n* = 12)	**TD** (*n* = 11)
McNemar's Test		
χ^2, 1 degree of freedom	0.250	3.200
p-value, two-tailed	0.617	0.074
Φ *[Qualitative Effect Size]*	0.174 *[Small]*	0.289 *[Small]*

Table 6

Participant ID #	Implicit-only	Mastery? (80%+)	Explicit-added	Mastery? (80%+)
RC-ASD 001	*	n/a	80	Y

RC-ASD 002	*	n/a	100	Y
RC-ASD 003	50	N	100	Y
RC-ASD 004	50	N	*	n/a
RC-ASD 005	*	n/a	50	N
RC-ASD 006	50	N	*	n/a
RC-ASD 007	90	Y	50	N
RC-ASD 008	*	n/a	60	N
RC-ASD 009	30	N	50	N
RC-ASD 010	*	n/a	20	N
RC-ASD 011	10	N	20	N
RC-ASD 012	30	N	30	N
RC-ASD 013	20	N	50	N
RC-ASD 014	50	N	20	N
RC-ASD 015	60	N	100	Y
RC-ASD 016	50	N	50	N
RC-ASD 017	30	N	50	N
RC-ASD 019	50	N	90	Y
RC-ASD 020	50	N	40	N

Note. For all participants, an asterisk (*) denotes non-completion of task condition

Table 7

Participant Scores as Mastery/Non-Mastery for Both Instructional Conditions (TD)

Participant ID #	Implicit-only	Mastery? (80%+)	Explicit-added	Mastery? (80%+)
RC-TD 001	80	Y	100	Y
RC-TD 002	30	N	100	Y
RC-TD 003	100	Y	80	Y
RC-TD 004	100	Y	90	Y
RC-TD 005	40	N	90	Y
RC-TD 006	50	N	90	Y
RC-TD 007	100	Y	100	Y
RC-TD 008	40	N	20	N
RC-TD 009	50	N	*	n/a

RC-TD 010	60	N	80	Y
RC-TD 012	80	Y	100	Y
RC-TD 013	60	N	90	Y

Note. For all participants, an asterisk (*) denotes non-completion of task condition

Table 8

Overall Accuracy on Judgment Task for ASD Group

		Condition	
% Correct		Explicit-added	Implicit-only
	Average	54.17	43.33
	SD	28.11	21.03
	Min-Max	20 - 100	10 -90

Research Question 2: Comparison of Performance of ASD and TD Group

To answer this question, ASD and TD participant performance was compared using a Fisher's Exact chi-square test for small sample sizes based on the *Mastery/Non-Mastery* dichotomy described above.

For the implicit-only condition, the two-tailed p-value equaled 0.062, indicating no statistically significant association between the groups (*ASD/TD*) and outcomes (*Mastery/Non-Mastery of Judgement Task*, where *Mastery* ≥ 80%). From this, it was determined that $\chi^2 = 4.338$ with a corresponding Phi coefficient of $\Phi_{Implicit} = 0.408$. This coefficient is considered a moderate effect size. As this value is calculated independent of sample size, there is a possibility that, were the sample size larger, a statistically significant relationship would be observed.

For the explicit-added condition $p = 0.002$, and thus the relationship between neurotype (ASD or TD) and performance is considered statistically significant.

Additionally, given $\chi^2 = 10.155$, a Phi coefficient of $\Phi_{Explicit} = 0.602$ was calculated, corresponding to a large effect size. Given the relatively small sample size and $p = 0.002$, this points to strong relationship between neurotype and performance in the explicit-added condition independent of sample size. See Tables 9 and 10 for the contingency table and related statistic values, respectively.

Table 9

Chi-Square Contingency Table, Fisher's Exact Test

		Group		
		ASD	**TD**	
Condition		(*n* = 14)	(*n* = 12)	TOTAL
Implicit				
	Master (80%+)	1	5	**6**
	Non-Master (< 80%)	13	7	**20**
	TOTAL	**14**	**12**	***26***
		ASD	TD	
		(*n* = 17)	(*n* = 11)	TOTAL
Explicit				
	Master (80%+)	5	10	**15**
	Non-Master (< 80%)	12	1	**13**
	TOTAL	**17**	**11**	***28***

Table 10

Statistical Analysis of Intergroup Performance, ASD/TD Comparison

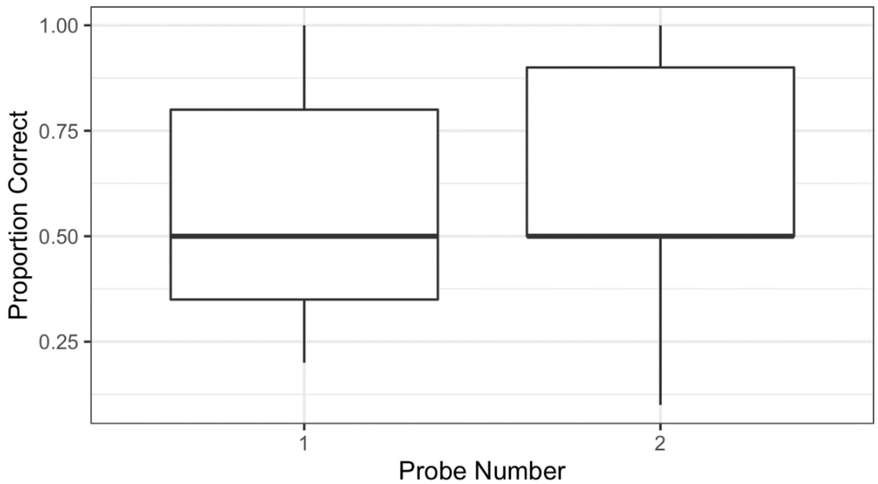
	Condition	
	Implicit	**Explicit**
Statistical Test	(n_{ASD} = 14; n_{TD} = 12)	(n_{ASD} = 17; n_{TD} = 11)
Fisher-Exact Test		
χ^2, 1 degree of freedom	4.338	10.155
p-value, two-tailed	0.062	0.002
Φ *[Qualitative Effect Size]*	0.408 *[Moderate]*	0.602 *[Large]*

Research Question 3: Impact of Language and Cognitive Abilities on Performance

To begin the model-fitting procedure, Probe Number was added to the base model to examine whether performance differed between the first and second probe. Next, we added Item Order (e.g., 1, 2, 3) to the model as a continuous variable. This allowed for examination of whether performance changed over the course of the 10 items in the probe. The next variable added into the models was Morpheme Type (i.e., gender; person). Finally, Instruction Type (i.e., implicit-only; explicit-added) was added. The most complex model that fit the data better than the next-least-complex model was the one in which there was a significant fixed effects for only Probe Number. This model fit the data better than the next-least-complex significant model to converge (χ^2[df = 1] = 6.29, p = 0.012). This effect is displayed in Figure 1 and indicates stronger performance on the second probe.

Figure 4

Accuracy on Receptive Judgement Probe by Probe Number



Next, we examined how factors related to individual differences predicted trial success or failure. We entered the factors in the following order: participant age, diagnosis, language ability as measured by Core language score from the CELF-4 nonverbal IQ as measured by the Raven's Matrices standard score, executive function as measured by parent-reported abilities on the BRIEF parent-reported gender, and performance on metalinguistic awareness probes (i.e., Word Swap, Morpheme Production, and Grammatical Judgement). The model with the best fit was the one that included diagnosis, parent-reported gender, and performance on the morpheme production task (χ^2[df = 1] = 4.29, p = 0.038). There were no significant interactions among these variables. Participants in the TD group outperformed those in the ASD group, AMAB participants outperformed AFAB participants, and there was a positive relationship between performance on the Receptive Judgement Probe and the Morpheme Production Task. Figures 2, 3, and 4 display the effects of diagnosis, parent-reported gender, and performance on the morpheme production task, respectively. Table 11 includes the parameters for this significant model.

Figure 5

Accuracy on Receptive Judgement Probe by Diagnosis

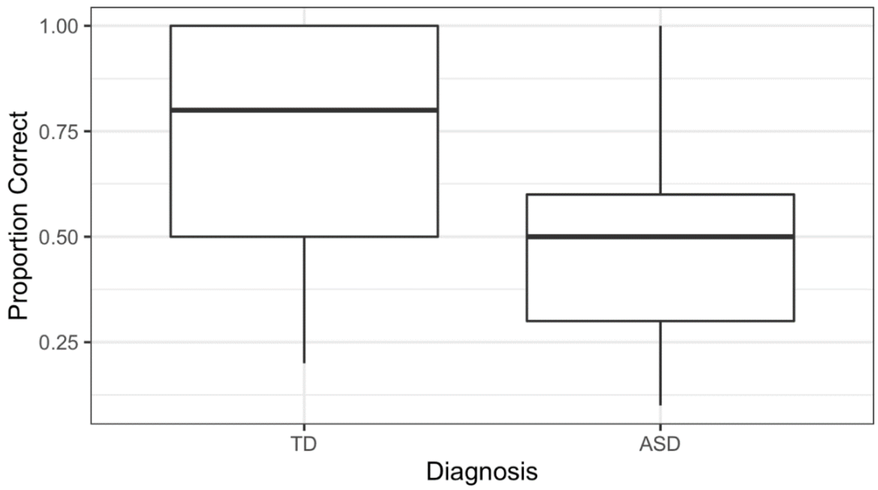


Figure 6

Accuracy on Receptive Judgement Probe by Gender

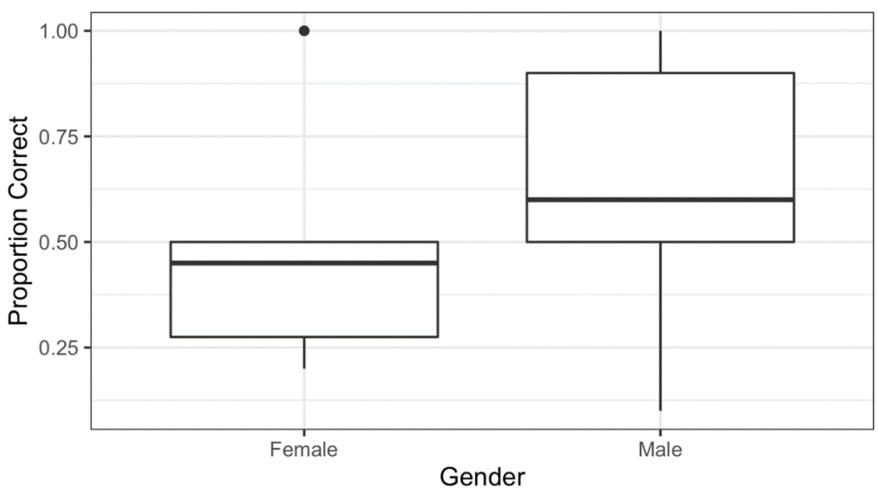


Figure 7

Scatterplot to Display Relationship Between Proportion Correct on Receptive Judgement Probes and Morpheme Production Task

Table 11

Parameters for Significant Model

Factor	Estimate	Standard Error	z-value	Pr(>|z|)
(intercept)	0.010	0.176	3.014	0.003
Diagnosis	-0.404	0.180	-2.242	0.025
Gender	0.731	0.189	1.738	0.82
Morpheme Production Task	0.409	0.192	2.132	0.033

Discussion

The purpose of this study was to examine whether combined explicit-implicit instruction in morphosyntax would lead to better learning outcomes for children with ASD than implicit instruction alone. We examined whether differences in neurotype (i.e., ASD versus TD) and/ or specific child-level characteristics, such as language, cognition, executive functioning, metalinguistic abilities, parent-reported gender, and age, would impact children's success in acquiring novel grammatical forms, and whether these characteristics would predict better learning under one instructional condition over another (i.e., explicit-added vs. implicit-only instruction). We predicted that children with ASD would learn novel verb inflections more successfully when given combined explicit-implicit instruction, rather than implicit-only instruction; that TD children would outperform children with ASD on these learning tasks; and that increased scores on measures of executive functioning, metalinguistic awareness, and expressive language skills would predict better learning outcomes for all participants.

Overall, the results of this study indicated that combined explicit-implicit may have advantages over implicit instruction alone when teaching grammatical forms to children with ASD. It is important to note that the language-learning task was difficult for the children with ASD with either type of instruction. Study results indicated that TD children acquire these forms more easily than children with ASD with either implicit instruction alone or a combined explicit-implicit combined instruction. Study findings did not indicate strong associations between the measured cognitive and language skills and success at acquiring morphological forms.

Research Question 1: Comparison of Performance in Implicit-Only and Explicit-Added Instructional Conditions

Based upon prior research and understanding of the language and cognitive abilities of children with ASD, it was predicted that participants with autism would have greater success when provided with explicit-added, rather than implicit-only, instruction. The findings of this study indicate that some of the TD and some of the ASD children had greater success with the explicit-added condition than the implicit-only condition. Specifically, 10 children in the TD group met the mastery level in the Explicit-added condition and only 5 did in the Implicit-only condition. In the ASD group, 3 children met the mastery level in the Explicit-added condition and only 1 child did in the Implicit-only condition. At the group level, there were no statistically significant differences between conditions for either group and these comparisons were associated with small effect sizes.

An important factor to consider in this analysis, however, is that the majority of children in the ASD group (8 of 12 participants) did not meet mastery criteria for either condition. This means that while many children in the ASD group did attain higher levels of accuracy in the explicit teaching condition, this percent change was not captured in the statistical analyses. The average performance of children in the ASD group was 11% higher in the explicit-added than the implicit-only condition, but no significant association was found in the mixed models. Overall, 7 of 12 participants in the ASD group showed higher performance in the explicit-added condition when compared to performance in the implicit-only condition, while the performance of 2 participants remained stable. Results also indicated that providing only implicit instruction did not demonstrate advantages over providing combined explicit-implicit instruction; thus, results indicated that there are no disadvantages to adding an explicit teaching component to existing implicit teaching approaches, and there may be some benefits to doing so.

Research Question 2: Comparison of Performance of ASD and TD Group

Given that research has shown that children with ASD often demonstrate impairments in morphosyntax (Bartolucci et al., 1980; Eigsti et al., 2007; Huang & Finestack, 2020; Roberts et al., 2004; Tager-Flusberg, 1989; Wittke et al., 2017), it was predicted that the typically-developing children would have greater success learning the novel-bound morphemes relative to the children with ASD. The difference in performance between TD and ASD participants was considered statistically significant for the explicit-added teaching condition ($p = 0.002$), but not in the implicit-only condition ($p = 0.062$). However, for both conditions the effect size was moderate or greater ($\Phi_{Explicit} = 0.602$; $\Phi_{Implicit} = 0.408$).

While, as noted above, both groups showed better performance in the explicit-added learning condition, few of the children in the ASD group reached mastery level for either condition. This may point to the difference in learning conditions or structure required for mastery between the two participant groups. As this was a single teaching session, it is difficult to determine at what level each child struggled with the task and what further instruction would have been beneficial in this setting. However, it is evident that there were substantial differences in performance between the ASD and TD groups; potential contributing factors were examined further in Research Question 3.

Research Question 3: Impact of Language and Cognitive Abilities on Performance

It was predicted that language and cognitive abilities, especially expressive language and metalinguistic awareness skills, would have a positive relationship with the degree of success each child had in the acquisition of novel, bound morphological forms. Additionally, it was assumed that the order of tasks (i.e., whether the implicit-only or explicit-added teaching condition was shown to the child first) would have a positive impact on overall success.

Overall, language abilities as measured by standardized assessments seemed to have little effect relative to achievement of mastery criteria (80% accuracy or greater) on the Receptive Judgement Probe, as there was no statistically significant association between these two variables. No statistically significant association between performance on the probe and age, nonverbal IQ, executive functioning, or performance on two of the three metalinguistic awareness probes (Word Swap & Grammatical Judgement) was found. Additionally, it was determined that task order did impact performance.

The single language measure that positively correlated with performance on the Receptive Judgement Probe was the Morpheme Production Task, or "Wug Test." While one is a receptive and one an expressive task, there is a distinct similarity between these two tasks, which could account for this correlation—they both require the child to engage with novel nonwords or inflections that do not exist in English. While the other two metalinguistic awareness tasks depended on inversion of known word meanings or grammatical forms, neither introduced novel words or constructions. For both the Receptive Judgement Probe and the Morpheme Production Task, the child must not only be able to manipulate or comprehend known English words or forms but, additionally, be able to apply known forms to novel (nonword) nouns (Morpheme Production Task) or apply novel verb inflections to known verbs (Receptive Judgement Probe). This requires higher level language skills that may not be captured in the other portions of the metalinguistic awareness probe.

Lastly, as noted above, these statistical analyses further confirmed that the TD group significantly outperformed the ASD group on the Receptive Judgement Probe and that, additionally, AMAB participants outperformed AFAB participants. While this latter point may have been statistically true, it is also important to note that AFAB participants only made up 29% (9 of 31) of participants across the two groups and thus were not equally represented in this small sample.

Limitations & Considerations for Future Research

Sample Size and Characteristics

One clear limitation of this study was related to sample size.. Given the complexity of the experimental task and the limitation of a single learning session in which to complete it, this smaller sample size likely did not capture a true spectrum of responses across language and cognitive abilities. As there was no statistical correlation between age and performance, the age range included in this study (5- to 8-year-olds) seems to be an appropriate peer-matched age group and would be appropriate to continue to use for future studies on this topic.

Related specifically to the participants with autism, researchers have found considerable variability in the language abilities of children in this demographic and this variability may be an important consideration in future studies. As previously discussed, Wittke et al. (2017) found that children with ASD in their sample could be grouped according to four distinct language profiles: (1) those with age-typical language skills, (2) those with little to no spoken language, (3) speaking children with impairments across a range of language and cognitive domains (e.g., vocabulary, syntax, morphology, nonverbal IQ scores), and (4) children with strengths in nonverbal IQ and vocabulary but specific deficits in grammatical language skills. Children in the fourth group demonstrate language profiles similar to those of children with DLD, consistent with other research that has shown parallels in impairments and efficaciousness of language interventions for these two demographics (Huang & Finestack, 2020; Riches et al., 2010; Tuller et al., 2017; Williams et al., 2008; Wittke et al., 2017). Given this, and the evidence that children with DLD may benefit more from explicit-based than implicit-based morphosyntactic instruction, it is possible that further division of children with ASD into subgroups based on language profile may demonstrate significant correlations between instructional condition and morphological form acquisition for children within particular subgroups.

Further regarding participant characteristics, it is important to note that all participants reported their race as white, and only 1 in 20 ASD participants and 1 in 13 TD participants reported their ethnicity as Hispanic/Latinx. This not only limits the child demographic to which these findings could be applied but is, additionally, not in any way representative of the ethnic and racial makeup of the city of Minneapolis. According to the 2019 census, individuals who identify as “White alone, not Hispanic or Latino” comprise only 60% of the overall population of the city, while “Black or African American alone” comprise 19.2% and “Two or More Races” represent 4.8% (U.S. Census Bureau, 2020). Considering how these percentages are then reflected in our school-based and clinical practices, it would be important to consider how these demographics are included (or systemically excluded) from studies such as this.

Participants' Completion of Experimental Tasks

Another limitation of this study, impacting the quantity of data available for analysis for some research questions, was the fact that multiple children (especially those in the ASD group) only completed one condition and thus intraparticipant performance values could not be attained for these participants. While some children were able to complete both conditions in a timely manner, one TD participant and seven participants with ASD were not able to return to the on-campus clinic or be seen in their home due to COVID-19 and related University lockdown and precautions. For future studies, assuring that all participants had opportunities to participate in both implicit-only and explicit-added teaching conditions would provide data that could be more consistently compared for all participants.

Experimental Design

Selection of Targeted Forms. A possible area for further investigation is whether children's performance would vary if, given otherwise identical procedures, the targeted morphological forms marked features that are common in English (e.g., singular vs. plural nouns, present vs. past verb forms), and whether differences in performance between those receiving implicit-only compared to explicit-added instruction would become more pronounced in that context. While verb inflections related to person do exist in English, English does not use different inflections for first- and second-person verb forms except for a few irregular verbs (e.g., the use of "I am" vs. "you are" for the verb "to be"). English also does not possess grammatical gender except in its use of pronouns and a limited number of nouns; English-language verbs are never inflected based on the gender of a subject, except in the case of subject-verb agreement for the gender-neutral singular pronoun, "they."

It is notable that, of the participants who completed the Receptive Judgement task within the Implicit Gender condition, only 1 out of 8 participants in the ASD group and two out of eight participants in the TD group achieved mastery criteria of 80% accuracy or higher; six out of eight participants with ASD and four out of eight TD participants received accuracy scores of 50% or lower. Three out of four TD participants (75%) achieved mastery within the Implicit Person condition, in contrast with two out of eight TD participants (25%) who achieved mastery within the Implicit Gender condition. Thus, one possibility is that participant performance was impacted by children's difficulty comprehending the concept of the use of verb inflections to mark the gender of a subject; this grammatical marker exists in very few of the world's major languages, with the exception of many Slavic languages, in which it exists as a form of agreement between a subject with grammatical gender and its corresponding verb (Browne, 2021). It is also unclear whether children's perception of which illustrations represented a "boy" and which represented a "girl" were in agreement with those of the examiner; these perceptions are likely to vary based on cultural, familial, and personal background.

Future research could also examine whether children's performance would vary if different novel morphological endings were selected. This study utilized word-final /f/ and /ʃ/ to mark inflected verbs. In English, these consonants can occur in word-final position only after a vowel or a liquid (/l/ or /r/); future research could examine whether children had more difficulty applying morphological endings not in accordance with English phonology. An additional consideration related to his would be whether the speech sound production and auditory discrimination skills of individual participants correlates with performance on either the Expressive Production or Receptive Judgement probes; speech sound production and auditory discrimination were not formally assessed for this study, but five participants with autism reportedly received speech-language therapy related to speech sound production (two with articulation errors, two with childhood apraxia of speech, and one with a history of "speech errors" that the parent reported were nearly resolved) and three participants with ASD were hard-of-hearing (including one of the participants with childhood apraxia of speech). Additionally, parents reported that three additional participants with ASD and one TD participant received speech-language therapy for nonspecific reasons that may have included speech sound disorders (e.g., "speech delay," "ASD"). The relationship between production and discrimination of speech sounds and application of morphological endings should be examined in future research, as well as whether this relationship is more pronounced when these endings incorporate particular phonemes and/or phoneme combinations.

Delivery of Instruction. As previously discussed, an additional limitation of this study is the fact that two-thirds of participants in the ASD group did not meet mastery criteria for acquisition of novel verb inflections under either instructional condition, making it more difficult to examine correlations between mastery and instructional condition as well as between mastery and individual participant characteristics such as executive functioning, metalinguistic awareness, and overall language abilities. As real-word instruction and intervention generally occurs over the course of many sessions over an extended duration (e.g., one hour per week for a year), and during this study, the instruction in each condition occurred only once and via only 16 trials, it is difficult to determine which children would have gone on to master these forms in a conventional therapy setting, and which instructional approach (i.e., implicit-only or explicit-added) would have been most effective and efficient in helping them to master these forms. Because participants performed significantly better on the second instructional task compared to the first, regardless of condition, it seems likely that providing additional instructional opportunities may result in progressive gains. Additionally, a longitudinal study would allow for investigation of whether acquisition of these forms would be maintained over time, and whether there is a correlation between instructional condition and maintenance.

Assessment of Performance. Within the current study, it was difficult to determine the extent to which participants understood the expectations of the experimental tasks, even aside from their ability to remember and apply novel grammatical forms. One potential way to address this in future research would be to assess comprehension of task expectations and background knowledge prior to introduction of the forms. For example, in the "person" task, participants could be asked to identify which illustration represented "I" (the space creature) and which illustration represented "you" (the image of a child) prior to introduction of verb inflections for person to ensure that errors did not reflect difficulty recognizing and remembering which image represented the 1st versus 2nd person.

Additionally, as previously discussed, Boucher and Anns (2018) developed their four-systems model of language development partially based on their review of earlier research showing that children with ASD often demonstrate strengths in discrimination alongside weaknesses in generalization (Davis and Plaisted-Grant, 2014; Pellicano &

Burr, 2012; Plaisted, O'Riordan & Baron-Cohen, 1998). The incorporation of a generalization probe to determine which intervention approach better generalizes to novel activities and naturalistic contexts would also provide useful information regarding whether one instructional condition may provide more meaningful and functional gains than the other. Participants could be provided with opportunities to use these forms when embedded within naturalistic activities, such as a story, interactive game, or role play activity. It is possible that one instructional condition may be more effective within the context of structured, focused tasks but less likely to generalize to novel or naturalistic activities. Thus, further investigation of skill generalization could provide more insight into which approach would provide greater long-term benefits to those receiving morphosyntactic instruction and interventions.

Assessment of Cognitive-Linguistic Factors. TD participants significantly outperformed participants with ASD, and there was considerable variation in within-group performance for the ASD group. Given that performance on the administered formal measures of cognition and language was not significantly correlated with performance on the experimental task, further information is needed regarding factors contributing to discrepancies in the performance of participants with ASD and TD participants, as well as those contributing to within-group individual differences in performance for the children with ASD. As previous research has shown varying degrees of impairment in executive functioning (Boucher and Anns, 2018, 2020; Maister et al., 2013; Walenski, Mostofsky, Gidley-Larson, & Ullman, 2008; Walenski, Mostofsky, & Ullman, 2014; Walenski, Tager-Flusberg, & Ullman, 2006) and specific forms of memory (Demetriou, DeMayo, M. & Guastella, 2019; Geurts, Sinzig, Booth, and Happé, 2014; Maister et al., 2013; Pellicano, 2010), further assessment of overall executive functioning abilities as well as specific assessments of attention and memory could provide increased insight into factors predicting acquisition of morphosyntactic forms in future research.

Conclusion

The current study aimed to better understand whether deductive (explicit-based) or inductive (implicit-based) grammatical instruction would correlate with better learning outcomes for children with ASD, as well as how their performance under both conditions would compare to the performance of their typically-developing, age-matched peers. Although children with ASD increased their accuracy in identifying correct use of novel verb inflections by approximately 11% when given explicit-implicit combined instruction rather than implicit instruction alone, only 4 out of 12 children in the ASD group who completed tasks under both instructional conditions achieved mastery in either instructional condition (one in the explicit-added condition and three in the implicit-only condition) and none achieved mastery in both conditions. As a result of these very low rates of mastery in either condition, no statistically significant relationship between mastery and instructional condition emerged.

In contrast, 10 out of 11 typically-developing children who completed tasks under both instructional conditions achieved mastery in at least one condition. Five of these children achieved mastery in the explicit-added condition but not the implicit-only condition, and another five achieved mastery in both instructional conditions. Thus, typically-developing children significantly outperformed children with ASD under both the implicit-only and explicit-added conditions as well as overall.

When all participants (those from both the ASD and TD groups) were combined into a single group, there was no statistically significant relationship between participants' performance on formal assessments of cognitive and language skills and their performance on the experimental probe.

Overall, this study demonstrated that children with ASD had more difficulty acquiring novel grammatical forms than typically-developing controls regardless of the modality in which instruction was delivered, and that while instructional condition was not correlated with their mastery of targeted verb inflections, they did perform more accurately when given explicit instruction in the rules for application of these inflections than when provided with implicit models alone. Further research with a greater number of participants and increased instructional opportunities is needed to determine whether children with ASD with particular cognitive and linguistic profiles learn morphosyntax better when explicit instruction is provided alongside more traditional implicit language modeling.

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