Research Article

Autism & Developmental Language Impairments

Autism & Developmental Language Impairments
Volume 4: 1–13

DOI: 10.1177/2396941519834717
journals.sagepub.com/home/dli
SAGE

An experimental study of word learning in minimally verbal children and adolescents with autism spectrum disorder

Robert M Joseph
Boston University School of Medicine, USA; Boston University, USA

Daniela Plesa Skwerer, Brady Eggleston, Steven R Meyer and Helen Tager-Flusberg
Boston University, USA

Abstract

Background and aims: When children hear a novel word, they tend to associate it with a novel rather than a familiar object. The ability to map a novel word to its corresponding referent is thought to depend, at least in part, on language-learning strategies, such as mutual exclusivity and lexical contrast. Although the importance of word learning strategies has been broadly investigated in typically developing children as well as younger children with autism spectrum disorder, who are usually language delayed, there is a paucity of research on such strategies and their role in language learning in school-age children and adolescents with autism spectrum disorder who have failed to develop fluent speech. In this study, we examined the ability of minimally verbal children and adolescents with autism spectrum disorder to learn and retain novel words in an experimental task, as well as the cognitive, language, and social correlates of these abilities. We were primarily interested in the characteristics that differentiated between three subgroups of participants: those unable to use word learning strategies, particularly mutual exclusivity, to learn novel words; those able to learn novel words over several exposure trials but not able retain them; and those able to retain the words they learned.
Methods: Participants were 29 minimally verbal individuals with autism spectrum disorder from 5 to 17 years of age. Participants completed a computerized touchscreen novel-word-learning procedure followed by assessments of immediate retention and of delayed retention, two hours later. Participants were grouped according to whether they passed/failed at least 7 of 8 (binomial $p < .035$) novel word learning trials and 7 of 8 immediate or delayed retention trials, and were compared on measures of nonverbal IQ, receptive and expressive vocabulary, phonological processing, joint attention and symptom severity.
Results: Of 29 participants, 14 failed both learning and immediate retention, 8 passed learning but failed immediate retention, and 7 passed both learning and immediate retention. Group performance was highly similar for delayed retention. Language level, particularly expressive vocabulary, differentiated between participants who did and did not succeed in retention, even while controlling for differences in nonverbal IQ.
Conclusions: The ability of minimally verbal school-age children and adolescents with autism spectrum disorder to identify the referents of novel words was associated with nonverbal cognitive abilities. Retention of words was associated with concurrent expressive language abilities.
Implications: Our findings of associations between the retention of novel words acquired in a lab-based experimental task and concurrent language ability warrants further investigation with larger samples and longitudinal research designs, which may support the incorporation of contrastive word learning strategies into language learning interventions for severely language-impaired individuals with autism spectrum disorder.

Keywords

Autism, minimally verbal, fast mapping, word learning, word retention

Corresponding author:
Robert M Joseph, Department of Anatomy and Neurobiology, Boston University School of Medicine, 72 E. Concord St., L-816 Boston, MA, USA.
Email: rmjoseph@bu.edu

Introduction

Although impairment in social reciprocity and communicative abilities (i.e. language pragmatics) and the presence of restrictive and repetitive behaviors are the defining symptoms of autism spectrum disorder (ASD), impaired development of structural language is one of the most common associated characteristics of ASD. Most preschool children with ASD are delayed in the acquisition of spoken language (Anderson et al., 2007; Howlin, Magiati, & Charman, 2009), but the majority attain various levels of language fluency over the school years (Pickles, Anderson, & Lord, 2014). However, approximately 30% of individuals with ASD never attain speech beyond a limited repertoire of words and simple phrases (Bal, Katz, Bishop, & Krasileva, 2016; Tager-Flusberg & Kasari, 2013).

Given that the development of fluent speech by 5 years of age is one of the most significant prognostic factors of longer-term adaptive outcomes among individuals with ASD (Billstedt, Carina Gillberg, & Gillberg, 2007), research into the underlying causes of language delay and deficit in ASD, and corresponding remedial strategies, has tended to focus on younger children with ASD (Tager-Flusberg & Kasari, 2013). More recently, following an initiative by the U.S. Interagency Autism Coordinating Committee (IACC; https://iacc.hhs.gov/publications/strategic-plan/2011), increasing research efforts have been directed toward characterizing and understanding the language deficits in children with ASD who remain minimally verbal at school age and beyond (Bal et al., 2016). In the present study, we investigated word learning abilities among minimally verbal school-aged children with ASD using an experimental touch-screen task that involved the contrastive presentation of familiar versus novel words and their referents and that tested participants' ability to learn and retain the novel words.

Early work on word learning focused on young children's ability to rapidly form an association between a novel word and its referent after only one or few trials, a process referred to as fast mapping (cf. Carey & Bartlett, 1978). In a typical fast mapping experiment, a child is presented with a novel word in the context of choosing between a familiar object (known label) and unfamiliar object (unknown label). The finding that the child tends to associate the novel word with the unfamiliar object has been replicated in many studies of typically developing children beginning in later infancy through toddlerhood (Clark, 1990; Golinkoff, Hirsh-Pasek, Bailey, & Wenger, 1992; Markman, Wasow, & Hansen, 2003).

The ability of a child to fast map a novel word to its intended referent has been hypothesized to depend on word learning strategies, including mutual exclusivity (Markman & Wachtel, 1988) and lexical contrast (Clark, 1990), which are overlapping constructs that refer to children's ability to make inferences about the meaning of a novel word based on their knowledge of other words or concepts that are present during the learning phase in an experimental context. Whether such learning strategies provide a complete explanation for the ability of typically developing children to map novel words to their referents has been extensively investigated. In particular, whether the rapid learning of novel words also depends on the child's ability to monitor the speaker's intent (via ostensive cues such as the speaker's direction of gaze or pointing) has been widely studied, and the preponderance of evidence has indicated that it does (Baldwin, 1993; Baldwin & Moses, 2001; Bloom & Markson, 1998; Tomasello & Barton, 1994).

Given that children with ASD tend not to use ostensive cues such as gaze direction and pointing to establish shared attention with other people (Mundy, Sigman, & Kasari, 1990), the role of social cues in their performance on word learning tasks has also been extensively investigated, with conflicting findings. In the first such study, Baron-Cohen, Baldwin, and Crawson (1997) found that school-age children with ASD did not use the speaker's direction of gaze to map new words onto their intended referents. In a subsequent study, Preissler and Carey (2005) demonstrated that school-age children with ASD were largely successful at fast mapping novel words but, in contrast to a control group of typically developing toddlers, did not benefit in their performance from referential intention cues. Invoking parsimony, these authors concluded that basic constraints in language learning or general inferential abilities are sufficient, independently of social cues, to enable children with ASD to assign novel words to objects in the world. Yet, more recent studies examining word learning with a range of paradigms have demonstrated that children with ASD can use social cues to map novel words to their referents (Akechi et al., 2011; Akechi, Kikuchi, Tojo, Osanai, & Hasegawa, 2013; Bean Ellawadi, & McGregor, 2016; Hani, Gonzalez-Barrero, & Nadig, 2013; Luyster & Lord, 2009; McDuffie, Yoder, & Stone, 2006; Norbury, Griffiths, & Nation, 2010). Notably, the participants in these studies were generally higher-ability children with ASD, in contrast to the participants in the earlier studies conducted by Baron-Cohen et al. (1997) and Preissler and Carey (2005), whose participants were more similar in nonverbal IQ and language level to those in the present study.

Although much less studied than social attention, another factor of interest in novel word learning has been phonological processing. In general, most research has failed to provide evidence that phonology is specifically impaired in ASD (Eigsti, de Marchena, Schuh, & Kelley, 2011). However, based on studies focusing more specifically on the role of phonological processing in word learning in ASD, Norbury and colleagues (Henderson, Powell, Gareth Gaskell, & Norbury, 2014; Norbury et al., 2010) have proposed that enhanced sensitivity to the phonological properties of novel words among children with ASD may detract from their ability to encode and consolidate these words semantically. Of note, these studies have been on verbal children with ASD. Other researchers studying fast mapping and language retention among cognitively and verbally impaired individuals with ASD (Abbeduto, McDuffie, Thurman, & Kover, 2016; McDuffie, Kover, Hagerman, & Abbeduto, 2013) have hypothesized that deficits in phonological perception and memory may more basically hamper the ability of MV individuals to encode new words phonologically.

The relationship between experimental word learning via fast mapping and the actual retention of novel words learned, as well as vocabulary development in general, has been widely researched and debated in the literature on young typically developing children (Bion, Borovsky, & Fernald, 2013; Rice, Buhr, & Nemeth, 1990). Only two studies have examined the relationship of experimental word learning via fast mapping to language development in children with ASD, and neither measured retention of the novel words learned. First, in a longitudinal study of 59 preschool children with ASD, Venker, Kover, and Weismer (2016) reported that performance on a fast mapping task was positively associated with receptive and expressive language abilities concurrently at age 3 and at a follow-up at age 5 years. Although the association between word learning and expressive language at age 3 was no longer significant when analyses were adjusted for nonverbal IQ, associations held with receptive language at both age 3 and 5 years. In a second study, including 29 low-verbal and low-IQ school-age children with ASD, McDuffie et al. (2013) found that fast mapping ability was not significantly correlated with concurrent receptive and expressive language or nonverbal IQ, but all associations trended in the expected direction. Otherwise, we know of no study of children with ASD that has examined the retention of novel words learned via referent disambiguation in an experimental task, or the relationship between retention and general language abilities.

In the present study, our aim was to examine word learning and associated abilities in minimally verbal children and adolescents with ASD with the goal of characterizing a key aspect of language learning in these groups and identifying potential strategies for remediation among children who at age 5 years and older are at risk of never acquiring functional language. Toward this aim, we administered computerized, touch-screen word learning training (Figure 1(b)) and word retention (Figure 1(c) and (d)) tasks, adapted from Bion et al. (2013) to be appropriate to the age, abilities and behavioral repertoires of our participants, and that did not involve any ostensive cues. We examined performance on these tasks to a number of independently measured variables, including nonverbal IQ, receptive and expressive vocabulary, phonological processing, joint attention, and social-communicative symptom severity. We focused our analyses on differences between participants who were and were not able to learn novel label-object mappings and, more specifically, on differences between individuals who retained the novel words they learned and those who did not.

Methods

Participants

Participants were 29 children and adolescents with ASD who ranged in age from 5 to 17 years. They were recruited from a variety of resources in the community via news and social media, including schools and clinics. Based on parent report, all the participants enrolled had little to no functional language. They came from homes in which English was the primary spoken language, had normal or corrected-to-normal vision and hearing, and did not have significant neurological impairment. Informed consent was obtained from the parents, and study procedures were approved by the Boston University Institutional Review Board.

Diagnosis of ASD

All participants, with the exception of one child for whom an informant was unavailable, met criteria for autism on the Autism Diagnostic Interview – Revised (ADI-R; Rutter, Le Couteur, & Lord, 2003), a semi-structured parent interview assessing reciprocal social interaction, communication, and restricted and repetitive behaviors symptoms. In addition, all participants met criteria for autism via direct behavioral observation using the ADOS, a semi-structured interactive play interview in which the examiner creates a series of social occasions and presses to assess child behaviors relevant to an ASD diagnosis. Participants aged 5 through 11 years ($n = 17$) were assessed with Module 1 of the Autism Diagnostic Observation Schedule-2 (ADOS-2; Lord et al., 2012). Participants aged 12 through 17 years ($n = 12$) were assessed with the Adapted ADOS (A-ADOS; Hus et al., 2011), which uses play materials more appropriate and engaging for adolescents. For children administered the A-ADOS, social-affective and restrictive and repetitive behavior algorithm scores

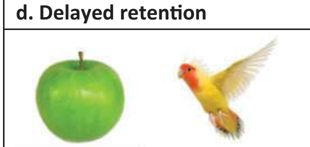
Trial type	Stimuli per trial	Stimuli type	Number of trials	Pass criterion	N (of 29) passing
a. Touchscreen training					
	1	Familiar	4	≥ 3	29
	1	Novel	4	≥ 3	29
b. Referent selection/learning					
	2	Familiar-Novel (FN)	12	≥ 10	14
	2	Familiar-Familiar (FF)	4	NA	NA
c. Immediate retention					
	2	Familiar-Familiar (FF)	8	≥ 7	14
	2	Familiar-Novel (FN)	8	≥ 7	8
	2	Novel-Novel (NN)	8	≥ 7	7
d. Delayed retention					
	2	Familiar-Familiar (FF)	8	≥ 7	13
	2	Familiar-Novel (FN)	8	≥ 7	8
	2	Novel-Novel (NN)	8	≥ 7	8

Figure 1. From left to right, familiar and novel object stimuli examples, number of stimuli presented per trial, number of trials, pass criteria, and number of participants passing in the (a) touchscreen training, (b) referent selection/learning, (c) immediate retention, and (d) delayed retention conditions.

and calibrated symptom severity scores (Hus, Gotham, & Lord, 2014) were calculated using ADOS-2 procedures (Hus & Lord, personal communication). For both the ADI-R and ADOS, higher diagnostic algorithm and calibrated symptom severity scores indicate more severe ASD symptoms. Participant characteristics are reported in Table 1.

Standardized measures of IQ, receptive vocabulary, and phonology

Nonverbal IQ was measured with the Leiter-3 (Roid, Miller, Pomplun, & Koch, 2013), which requires no expressive and minimal receptive language to complete. Receptive vocabulary was measured with the Peabody

Table 1. Participant characteristics (N = 29).

	Mean (SD)
Age	10.8 (3.9)
ADI-R scores[a]	
Social interaction	25.4 (3.8)
Communication	
Nonverbal	11.4 (2.2)
Verbal	8.0 (1.2)
Repetitive behaviors	5.6 (1.8)
ADOS calibrated symptom severity scores	
Social affect	7.0 (1.3)
Restricted and repetitive behaviors	8.7 (1.3)
Total	7.7 (1.3)
Leiter-3 scores	
Raw	49 (19)
Age equivalent (years)	4.5 (1.8)
Standard	68 (17)
PPVT-4	
Raw	38 (27)
Age equivalent (years)	3.0 (1.1)
Standard	33 (18)
	N
Sex (male/female)	21/8
Race/ethnicity	
African-American	2
Asian	2
White	21
Hispanic	0
Native Pacific islander	0
More than one race/unknown	4

ADI-R: Autism Diagnostic Interview – Revised; ADOS: Autism Diagnostic Observation Schedule; PPVT: Peabody Picture Vocabulary Test.
[a]One minimally verbal participant was missing ADI-R data.

Picture Vocabulary Test – 4 (PPVT-4; Dunn & Dunn, 2007). As in other minimally verbal ASD samples (Bal et al., 2016; Munson et al., 2008), paired-samples t-tests showed that participants obtained significantly lower PPVT-4 receptive language standard scores than Leiter-3 nonverbal cognitive ability standard scores, $t(28) = 12.0$, $p < .001$. The mean difference between standardized PPVT-4 and Leiter-3 scores was 34.9 (SD = 15.7).

Phonological processing was evaluated with the Kaufman Speech Praxis: Test for Children (KSPT; Kaufman, 1995) Part 2. The KSPT Part 2 assesses children ability to repeat a range of utterances, from single phonemes to two-syllable words with non-identical first and second syllables. Like tests such as The Children's Test of Nonword Repetition (CNRep; Gathercole, Willis, Baddeley, & Emslie, 1994), it measures children's short-term auditory skills, phoneme blending and combining, and speech production skills that underlie the ability to learn the sound patterns of new words and to acquire new vocabulary. KSPT data were not available for 7 adolescents.

ADOS expressive vocabulary and joint attention measures

A direct observational measure of expressive vocabulary was derived from each participant's ADOS assessment. Trained research assistants transcribed the ADOS assessment using Systematic Analysis of Language Transcripts software (Miller, Andriacchi, & Nockerts, 2011). All transcripts were prepared by one transcriber from the audiotapes and independently checked by a second transcriber using the video recording of the session; the two transcribers then discussed and resolved any disagreements (Condouris, Meyer, & Tager-Flusberg, 2003). Total number of different words (NDWs) was calculated for intelligible speech by deriving the total NDW roots each child produced. NDW rate was calculated by dividing the total NDW by the length of the ADOS in minutes to account for differences in total ADOS administration time.

Measures of response to and initiation of joint attention (IJA) were taken from the ADOS. Response to joint attention (RJA) is assessed with a structured task in which the examiner uses vocalization combined with gaze and then pointing cues to direct the child's attention to a target object. Initiation of joint attention is assessed on the basis of the child's spontaneous attempts to direct the examiner's attention, with vocal, gaze and/or gestural cues, to an object or event for the purposes of sharing rather than requesting. Both RJA and IJA were coded on a scale of 0 to 2, with scores of 0 and 2 reflecting the presence or absence, respectively, of RJA and IJA. Scores of 1 were assigned, based on ADOS scoring criteria, when some evidence of RJA or IJA was present, but not sufficient to meet a score of 0.

Experimental procedure

Two research technicians conducted the experiment using a touch-screen computer monitor. One experimenter sat next to the participant in front of the computer screen to provide guidance and support, while the other sat perpendicularly at a slight distance to run the computerized experiment. Participants were seated in an adjustable upright armchair, with eye-level even with the center of the screen, approximately 60 cm from the monitor. On each trial, two color digital images of objects (or, on the initial eight computer touchscreen training trials, one image and an empty box) were presented to the left and right of center screen. Each image subtended 14.5° visual angle vertically and 12° horizontally, against a white background and separated by a space subtending 5° visual angle. One-half second after the appearance of each pair of objects, a digital voice recording of the word corresponding to one of the objects was presented at 80 db volume, prompting the participant to touch the image on the monitor.

The experimental procedure consisted of four parts: training to touch an object presented on the computer screen in response to an auditory word cue; learning two new word–object associations by repeatedly disambiguating novel from familiar objects over repeated trials; and immediate and delayed retention of novel word learning. The same visual stimuli were used for the touchscreen training, learning, and retention components of the procedure. There were four familiar objects – *car*, *chair*, *bird*, and *apple* – with two exemplars of each. Two novel stimuli – nonfunctional toy-like objects – were selected to be visually salient and easily discriminated from each other. Simple CVC labels – "teeg" and "dax" – were used to label novel objects to minimize the phonological processing and memory load (Abbeduto et al., 2016). The referent of the labels was counterbalanced across participants. See Figure 1 for stimulus presentation and number of trials for each component of the experiment.

Touchscreen training. The experiment began with eight training trials in which one stimulus was presented on one side of the computer screen alongside an empty box on the other side (Figure 1(a)). One of the familiar objects (car, chair, bird, or apple) was presented on four trials, and one of the novel objects (teeg or dax) was presented alternately on the other four trials. The aim of the training trials was to ensure that all participants were able to attend and comply with the basic procedure of registering a touchscreen response after hearing the auditory cue. The order of presentation of familiar and novel objects was intermixed. The participant was instructed to "touch the picture that goes with the word". If a participant failed to respond after the visual and auditory stimuli were presented, the experimenter modeled the correct response, and the trial was repeated. If the participant responded by touching the screen but did not register a response, the experimenter demonstrated an appropriate response with the palmar tip of the finger. All participants succeeded on at least 7 of 8 of these training trials with corrective feedback.

Novel word learning. Touchscreen training was immediately followed by 12 trials, each of which paired one of the 4 familiar objects with one of the two novel objects. On all 12 learning trials, the novel object was the correct response. These were intermixed with 4 additional trials pairing two familiar objects to reduce repetitiveness (Figure 1(b)). The aim of the learning procedure was to teach MV individuals the referents of the two novel words by presenting each with a known word and its referent over multiple trials (six trials for each novel word), following standard approaches that would allow the participant to use word learning strategies such as mutual exclusivity. All stimuli were counterbalanced for side of presentation. Trials were experimenter-paced so as to ensure that the participant was attending and to maintain compliance. No corrective feedback was provided on these trials, but the experimenter gave intermittent verbal praise for task compliance. Performance on the 12 familiar/novel trials in the initial learning condition was dichotomized, with 10 or more correct responses (binomial $p \leq .02$) counting as passing.

Immediate retention. Twenty-four additional trials were administered immediately after the learning trials (Figure 1(c)). These included eight trials with the two novel objects (novel/novel trials, i.e. immediate retention trials) in addition to eight trials with two familiar objects (familiar/familiar trials), and eight trials with one familiar and one of the two novel objects (four in which the novel object was the correct response – familiar/novel). The additional two trial types (familiar/familiar and familiar/novel) were included to reduce repetitiveness and to allow assessment of the relationship between learning novel words via mutual exclusivity/lexical contrast and novel word retention within the same experimental run. The order of the 24 trials was intermixed. All stimuli were counterbalanced for side of presentation. This procedure, including intermixing of trial type, was modeled after one developed by Bion et al. (2013) to assess the association between learning a novel word via fast mapping and the ability to retain the link between that novel word and its referent in the absence of a known referent (i.e. compared with another novel referent). Performance on the eight familiar/familiar trials, the eight familiar/novel trials and eight novel/novel trials in each of the retention conditions was dichotomized, with 7 or 8 correct responses (binomial $p \leq .035$) counting as passing. For example, a child could respond accurately to eight familiar/familiar trials, to 7 familiar/novel trials, and to five novel/novel trials, thus passing the first two trial types (FF, FN) but failing the third (NN).

Delayed retention. The retention trials were re-administered 2 hours after the immediate retention test in exactly the same format, again including familiar/familiar and familiar/novel trials in addition to novel/novel trials. Pass and fail criteria were the same as in the immediate retention condition. During the intervening two hours, participants completed standardized cognitive, language, and behavioral test measures, with breaks as needed.

Data analyses

Children's performance across these three trial types in the immediate and delayed retention conditions was the main focus of our analyses. Accordingly, we divided our sample into three groups based on performance on these trials: familiar–novel fail/novel–novel fail (FN−/NN−); familiar–novel pass/novel–novel fail (FN+/NN−); and familiar–novel pass/novel–novel pass (FN+/NN+). From among participants who succeeded on familiar/novel trials in the retention condition, we were most interested in differences between those who retained the meaning of the words from the familiar/novel trials on the novel/novel trials and those who did not.

In our primary analyses, we examined differences among these three subgroups in nonverbal IQ, receptive and expressive vocabulary, phonology, joint attention, and social symptom severity (ADOS social-affective calibrated symptom severity score) using one-way ANOVA, separately for the immediate and delayed retention conditions. We followed up significant ANOVA findings with least-significant-difference pairwise comparisons (used to increase power to detect differences among the relatively small subgroups). In addition, when there were significant subgroup differences in general cognitive ability, we repeated ANOVAs with significant results statistically controlling for nonverbal IQ with ANCOVA. Statistical analyses were conducted with SPSS Version 24.

Results

All 29 participants completed the learning trials and two retention tests. However, the majority of participants required redirection from the examiner to attend to the computer monitor before a trial was presented. In the immediate retention test phase, 15 of 29 participants required redirection to the computer on more than one trial. In the delayed retention test, 10 of 29 participants required similar redirection.

Novel word learning

Of the 29 participants, 14 (48%) met the pass criterion of ≥10 of 12 FN trials correct. Accuracy scores of those passing versus failing were 11.4 (SD = 0.9) and 6.4 (SD = 2.3), respectively, $t(28) = 7.8$ $p < .001$. Participants were generally consistent in their performance between the initial 12 FN learning trials and the eight FN trials embedded in the immediate retention condition. Of the 29 participants, 12 passed and 12 failed in both the learning and retention conditions, and 5 performed inconsistently across conditions. The mean retention condition FN scores of MV children who (1) failed in both the learning and retention conditions, (2) passed in either condition, or (3) passed in both conditions were 4.6 (SD = 1.8), 6.5 (SD = 1.0), and 7.8 (SD = 0.6), respectively, out of a possible total score of 8; $F\ (2,26) = 17.2$, $p < .001$.

Immediate retention

As shown in Table 2, the dichotomizing criteria used to define the three FN/NN subgroups were reflected in the differences in mean accuracy on familiar–familiar, $F\ (2,26) = 12.2$, $p < .001$, familiar–novel, $F\ (2,26) = 23.4$, $p < .001$, and novel–novel trials, $F\ (2,26) = 27.9$, $p < .001$, in the immediate retention condition, supporting the subgrouping approach we used. The FN−/NN− subgroup had a significantly lower familiar–novel score than the FN+/NN− subgroup, which did not differ in familiar–novel performance from the FN+/NN+ subgroup. The FN+/NN− subgroup, however, scored significantly lower than the FN+/NN+ subgroup on novel–novel trials (see Table 2).

The three FN/NN subgroups did not differ in age, $F(2,26) = 1.5$, $p = .25$, but differed significantly on Leiter-3 nonverbal IQ, $F(2,26) = 3.5$, $p = .045$, PPVT-4 receptive language, $F(2,26) = 5.2$, $p = .012$, ADOS NDW, $F(2,26) = 6.3$, $p = .006$, and KSPT phonological processing, $F(2,19) = 3.7$, $p = .046$). They also differed on ADOS social-affective symptom severity, $F(2,26) = 3.5$, $p = .044$). In post hoc pairwise analyses, the FN+/NN+ subgroup (participants who retained novel words from the learning trials) were differentiated from both the FN−/NN− and FN+/NN− subgroups by having a higher ADOS NDW score. Also, the FN−/NN− subgroup was differentiated from the FN+/NN− and FN+/NN+ subgroups by having a lower KSPT phonological processing score.

There were no significant differences between FN/NN subgroups on ADOS RJA, $F(2,26) = 1.4$, $p = .26$, or ADOS IJA, $F(2,26) = .02$, $p = .98$. Regarding ADOS RJA scores, the entire sample was able to orient to a shared object of attention via the examiner's gaze/head-turning cues (83%) or pointing cues (17%). In contrast, only a small minority of the sample (10.3%) made a clear attempt to initiate joint attention for the purpose of sharing with the examiner.

To assess whether significant differences in nonverbal IQ might account for differences found in receptive and expressive language, phonological processing, and social symptom severity between the three FN/NN subgroups, we repeated these analyses using ANCOVA to control for nonverbal IQ (Venker et al., 2016). To

Table 2. Associated characteristics of performance on familiar–novel (FN) and novel–novel (NN) trials in the immediate retention condition.

	FN−/NN− (n = 14) Mean (SD)	FN+/NN− (n = 8) Mean (SD)	FN+/NN+[a] (n = 7) Mean (SD)	p[b]
Age	10.1 (4.2)	10.1 (3.8)	13.0 (3.1)	.25
Retention condition accuracy				
Familiar–familiar trials	5.1 (1.6)$^+$	7.3 (1.2)$^+$	7.7 (0.5)	.000
Familial–novel trials	4.8 (1.6)$^+$	7.6 (0.5)$^+$	7.9 (0.4)	.000
Novel–novel trials	4.4 (1.2)	4.9 (1.0)$^+$	7.7 (0.5)$^+$	.000
Leiter-3 raw score	41 (19)	55 (11)	60 (22)	.045
PPVT-4 raw score	24 (23)	45 (15)	58 (32)	.012
ADOS number of different words (NDW)/minute	0.5 (0.7)	0.8 (0.5)$^+$	2.1 (1.6)$^+$	.006
KSPT raw score[c]	23 (21)$^+$	44 (20)$^+$	48 (12)	.046
ADOS[d]				
Response to joint attention (RJA)	0.3 (0.5)	0.1 (0.4)	0.0 (0.0)	.26
Initiation of joint attention (IJA)	1.6 (0.7)	1.6 (0.5)	1.6 (0.8)	.98
Calibrated social-affective symptom severity	7.4 (1.0)	7.3 (1.7)	6.0 (0.8)	.044

ADOS: Autism Diagnostic Observation Schedule; PPVT: Peabody Picture Vocabulary Test; KSPT: Kaufman Speech Praxis: Test for Children.
[a]FN−/NN−: familiar–novel fail/novel–novel fail; FN+/NN−: familiar–novel pass/novel–novel fail FN+/NN+: familiar–novel pass/novel–novel pass.
[b]One-way ANOVA; *F*-values are reported in the text.
[c]FN−/NN−: n = 12; FN+/NN−: n = 6; FN+/NN+: n = 4.
[d]Higher scores indicate increased impairment.
$^+$Post hoc, least significance difference pairwise comparisons between contiguous means significant at $p \leq .05$.

determine if the critical assumption of homogeneity of regression slopes for ANCOVA (Tabachnick & Fidell, 2007) was met for each dependent variable for which there was a significant between-group difference, we examined whether there were interaction effects between subgroup and nonverbal IQ, which would violate this assumption. There were no interaction effects between subgroup and PPVT-4 receptive language, $F(2,23) = 0.4$, $p = .67$, ADOS NDW, $F(2,23) = 0.4$, $p = .70$, KSPT phonological processing, $F(2,16) = 0.2$, $p = .79$, and ADOS social-affective symptom severity, $F(2,23) = 0.2$, $p = .80$, consistent with the ANCOVA assumption of homogeneity of regression slopes across levels of the independent variable.

ANCOVAs showed a main effect of nonverbal IQ on PPVT-4 score, $F(1,25) = 6.5$, $p = .02$, and KSPT score, $F(1,18) = 4.4$, $p = .05$, a marginal effect on ADOS NDW, $F(1,25) = 3.9$, $p = .06$, an no effect on ADOS social-affective symptom severity, $F(1,25) = 0.36$, $p = .56$. With nonverbal IQ score included as a covariate, FN/NN subgroup effects on PPVT-4 receptive vocabulary, $F(2,25) = 2.02$, $p = .15$, and KSPT phonological processing, $F(2,18) = 1.0$, $p = .40$, were no longer significant, but remained significant for ADOS NDW, $F(2,25) = 3.9$, $p = .035$, and ADOS social-affective symptom severity, $F(2,25) = 3.5$, $p = .045$. In addition, post hoc pairwise comparisons showed that ADOS NDW ($p = .02$) and social-affective symptom severity ($p = .05$) differentiated the FN+/NN+ subgroup (children who retained novel words from the learning trials) from both the FN−/NN− and FN+/NN− subgroups, which did not differ on these variables ($p = .98$ for ADOS NDW and $p = .61$ for ADOS social-affective symptom severity).

Table 3. Consistency in performance between the immediate and delayed retention conditions.

Immediate retention	Delayed retention			
	FN−/NN−	FN+/NN−	FN+/NN+[a]	Total
FN−/NN−	12	2	0	14
FN+/NN−	1	5	2	8
FN+/NN+	0	1	6	7
Total	13	8	8	29

[a]FN−/NN−: familiar–novel fail/novel–novel fail; FN+/NN−: familiar–novel pass/novel–novel fail FN+/NN+: familiar–novel pass/novel–novel pass.

Delayed retention

Table 3 shows performance, and corresponding subgrouping of the participants, across the immediate retention and delayed retention conditions. As can be seen, performance was generally consistent,

Table 4. Associated characteristics of performance on familiar–novel (FN) and novel–novel (NN) trials in the delayed retention condition.

	FN−/NN− (n = 13) Mean (SD)	FN+/NN− (n = 8) Mean (SD)	FN+/NN+[a] (n = 8) Mean (SD)	p[b]
Age	10.4 (4.4)	10.8 (4.0)	11.3 (3.5)	.89
Retention condition accuracy				
Familiar–familiar trials	4.5 (1.7)[+]	7.5 (0.8)[+]	7.8 (0.5)	.000
Familial–novel trials	5.6 (0.5)[+]	7.4 (0.5)[+]	7.6 (0.5)	.000
Novel–novel trials	4.3 (1.4)	4.5 (1.4)[+]	7.6 (0.5)[+]	.000
Leiter-3 raw score	42 (19)	49 (16)	62 (19)	.083
PPVT-4 raw score	22 (20)	43 (19)	59 (30)	.004
ADOS number of different words (NDW)/minute	0.5 (0.7)	0.8 (0.6)[+]	1.9 (1.5)[+]	.013
KSPT raw score[c]	23 (20)	38 (25)	46 (13)	.088
ADOS[d]				
Response to joint attention (RJA)	0.2 (0.4)	0.3 (0.5)	0.0 (0.0)	.34
Initiation of joint attention (IJA)	1.5 (0.8)	1.9 (0.4)	1.5 (0.8)	.47
Calibrated social-affective symptom severity	7.2 (1.2)	7.4 (1.3)	6.4 (1.3)	.24

PPVT: Peabody Picture Vocabulary Test; ADOS: Autism Diagnostic Observation Schedule; KSPT: Kaufman Speech Praxis: Test for Children.
[a]FN−/NN−: familiar–novel fail/novel–novel fail; FN+/NN−: familiar–novel pass/novel–novel fail FN+/NN+: familiar–novel pass/novel–novel pass.
[b]One-way ANOVA; *F*-values are reported in the text.
[c]FN−/NN−: n = 10; FN+/NN−: n = 6; FN+/NN+: n = 6.
[d]Higher scores indicate increased impairment.
[+]Post hoc, least-significance-difference pairwise comparisons between contiguous means significant at $p \leq .05$.

with 23 of 29 participants classified the same across conditions. Most notably, the number of FN+/NN+ participants increased from 7 to 8 from the immediate to the delayed condition as a result of two participants moving from FN+/NN− to FN+/NN+, and one participant dropping from FN+/NN+ to FN+/NN−.

As shown in Table 4, the pattern of subgroup differences in mean accuracy on familiar–familiar, F (2,26) = 23.0, $p < .001$, familiar–novel, F (2,26) = 49.0, $p < .001$, and novel–novel trials, F (2,26) = 20.6, $p < .001$, in the delayed retention condition was similar to that found for the immediate retention, again supporting the subgrouping approach we used. In the delayed retention condition, the three FN/NN subgroups did not differ significantly in age, $F(2,26) = 0.12$, $p = .89$, or Leiter-3 nonverbal IQ, $F(2,26) = 2.7$, $p = .083$. As in the immediate retention condition, the subgroups differed on PPVT-4 receptive language, $F(2,26) = 6.9$, $p = .004$, and ADOS NDW, $F(2,26) = 5.2$, $p = .013$, but did not differ in ADOS social-affective symptom severity, $F(2,26) = 1.52$, $p = .24$. In post hoc pairwise comparisons, the FN+/NN+ subgroup (participants who retained novel words from the fast mapping trials) were differentiated from both the FN−/NN− and FN+/NN− subgroups by ADOS NDW. There were no significant differences between FN/NN subgroups on ADOS RJA, $F(2,26) = 1.1$, $p = .34$, or ADOS IJA, $F(2,26) = 0.8$, $p = .47$.

Discussion

We examined the ability to learn and retain the association between a novel word and its referent in a sample of children and adolescents with ASD specifically selected for having minimal expressive language at age 5 years or older. We found that about one-half of our MV participants were able to disambiguate and map a novel label to a novel object, and that about one-quarter maintained such novel word associations in an immediate and a two-hour-delay retention test. In contrast to prior studies of word learning in ASD, we focused on the differences between participants who actually retained the words they learned via lexical disambiguation and those who did not. To examine these differences, we divided participants into three subgroups: those unable to learn the new words over repeated novel referent selection trials; those able to learn words via novel referent selection but without retention: and those who retained the words they learned during the referent selection trials. Our analyses focused on the variables that discriminated between these subgroups in an immediate retention task and a two-hour delayed retention task.

Participants who were unable to disambiguate the referents of novel from familiar words had lower nonverbal IQ than those who were able to do so. This finding suggests that the ability to assign a novel word to an unfamiliar object, rather than a familiar object for which the child already has a label, depends on inferential reasoning processes similar to those contributing to nonverbal IQ. This could mean that there is a minimum level of cognitive ability required to associate a novel label with an unknown referent, which would have important implications for incorporating word learning strategies such as lexical contrast and mutual exclusivity into language learning interventions.

Participants who retained the words they learned in the immediate retention condition had significantly higher PPVT-4 receptive vocabulary scores, but these subgroup differences in PPVT-4 receptive vocabulary were no longer significant when differences in nonverbal IQ were controlled. Differences in PPVT-4 scores were not significant in the delayed retention condition. In contrast, the ADOS NDW measure of expressive words robustly differentiated between participants who retained novel word–object mappings acquired in the disambiguation learning trials from those who did not in both the immediate and delayed retention test conditions, even when statistical adjustments for subgroup differences in nonverbal IQ were applied.

Participants who were unable to learn novel words had significantly lower KSPT phonological processing scores than those who succeeded in learning novel words. However, when subgroup differences in nonverbal IQ were statistically controlled, this difference was no longer significant. The association between low IQ and phonological processing deficits suggest that, in contrast to verbally fluent children with ASD, who have been hypothesized to be hyperattentive to the phonological features of novel words (Norbury et al., 2010), the most severely language-impaired MV individuals may lack basic skills in phonological perception, encoding, and production. The relationships between phonological abilities and word learning among MV individuals warrants further study, especially as phonological skills would be a critical factor to consider in any intervention aimed toward enhancing spoken language.

Although an ostensive cuing variable was not included in our experimental paradigm, we analyzed participants' ability to learn and retain novel words in relation to ADOS RJA and IJA. Neither of these variables differentiated between the FN/NN subgroups. The large majority of participants successfully responded to the examiner's vocal, gaze, head-turning or pointing cues to shift attention to a target of shared attention during the ADOS. This finding likely reflects the highly structured and compressed (five consecutive presses) nature of the ADOS RJA activity that may be more sensitive to social attention and communication deficits in younger children. In contrast, only a small minority of participants initiated joint attention. Yet, we did find that the ADOS measure of overall social-affective symptom severity was significantly lower among the subgroup who learned and retained novel words, even while adjusting for nonverbal IQ, in the immediate retention condition. This finding is consistent with evidence that a measure of a child's broader social-communicative abilities is a more sensitive predictor of success in novel word learning (Arunachalam & Luyster, 2016; Gliga, Elsabbagh, Hudry, Charman, & Johnson, 2012). However, in the delayed retention condition, although social-affective symptom severity scores trended in the same direction as in the immediate retention condition, the differences between them were no longer significant.

Our finding that half of our MV participants were easily able to disambiguate the referent of a novel from a familiar word without the support of ostensive cues is consistent with findings from previous studies of school-age children with ASD with significant language and cognitive deficits (McDuffie et al., 2013; Preissler & Carey, 2005). Regarding cognitive deficits, our analyses indicated that inferential reasoning skills were important to the ability to map a novel label to an unfamiliar and unnamed object. However, we were most interested in the retention of words acquired within the context of the novel word learning procedure we implemented. We found that the ability to map a novel word to its referent did not necessarily result in retention of the novel word, and that more advanced expressive vocabulary consistently differentiated participants who retained the novel words from those who did not. These findings suggest that the contrastive biases and principles that underlie word learning in typically developing toddlers could operate as a mechanism of language acquisition even among children with ASD who have failed to acquire fluent speech by school age. In addition, children who retained words had less severe social-communicative symptoms on the ADOS, suggesting that less impairment in pragmatic language and social reciprocity may support acquisition of novel words. Again, this finding did not extend to the delayed retention condition, indicating that it is unreliable or, possibly, that it is not applicable to longer-term encoding of newly acquired words.

The link we found between the immediate and delayed retention of novel words and more advanced vocabulary development, particularly in expressive language, was associational. Nonetheless, our experimental observations that individuals with ASD with very limited functional language appear able to acquire and retain vocabulary via lexical disambiguation might inform remedial strategies for vocabulary development that could foster more effective and adaptive expressive communication in MV individuals (Abbeduto et al., 2016; Wilkinson & Green, 1998). For example, the contrastive learning processes underlying lexical disambiguation in the context of word learning could be integrated into extant alternative and augmentative communication programs and platforms used by minimally verbal individuals with ASD (Sennott, Light, & McNaughton, 2016).

Although our findings highlight the importance of assessing retention of words learned via lexical contrast (Bion et al., 2013; Wilkinson, 2005), they are preliminary. Most notably, our sample size was small, limiting our power to detect group differences as well as the reliability of all but our most statistically robust findings. The latter is likely to explain, at least in part, the change of ANOVA results when the composition of the FN/NN subgroups changed only slightly between the immediate and delayed retention conditions. This underscores the need for replication of our findings with a larger sample. Nonetheless, we were able to demonstrate that just over one-half of a sample selected for being MV were able to learn novel words during a brief experimental task, one quarter retained these words over a two-hour delay, and that these abilities were associated with level of expressive vocabulary. For this reason, we argue that these initial findings are worthy of follow up with a larger sample as well as improved methodology. Regarding methods, our evaluation of factors potentially associated with word learning and retention depended on measures that were administered independently of the word learning task. Some of these factors, such as phonological load and direction of attention, may better help to inform the development of word learning techniques for remedial purposes if they are embedded and varied in the experimental procedure.

In summary, about half of our MV participants were able to learn novel label-object associations in an experimental task that supported contrastive word learning strategies, and one-quarter showed retention of the novel words. Nonverbal cognitive ability was associated with both the ability to learn novel words and the ability to retain them. Retention of newly learned words was strongly associated with expressive language abilities. Although preliminary, these findings suggest that language interventions built on the established word learning strategies, such as mutual exclusivity, warrant exploration as a way of promoting long-term word learning in children with ASD who are the most language impaired.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study was funded by an Autism Center of Excellence award from the National Institutes of Health (P01 DC 13027: PI, Tager-Flusberg).

ORCID iD

Robert M Joseph http://orcid.org/0000-0001-6879-0254

References

Abbeduto, L., McDuffie, A., Thurman, A. J., & Kover, S. T. (2016). Chapter three-language development in individuals with intellectual and developmental disabilities: From phenotypes to treatments. *International Review of Research in Developmental Disabilities*, *50*, 71–118.

Akechi, H., Kikuchi, Y., Tojo, Y., Osanai, H., & Hasegawa, T. (2013). Brief report: Pointing cues facilitate word learning in children with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *43*, 230–235.

Akechi, H., Senju, A., Kikuchi, Y., Tojo, Y., Osanai, H., & Hasegawa, T. (2011). Do children with ASD use referential gaze to learn the name of an object? An eye-tracking study. *Research in Autism Spectrum Disorders*, *5*, 1230–1242.

Anderson, D. K., Lord, C., Risi, S., DiLavore, P. S., Shulman, C., Thurm, A., . . . Pickles, A. (2007). Patterns of growth in verbal abilities among children with autism spectrum disorder. *Journal of Consulting and Clinical Psychology*, *75*, 594.

Arunachalam, S., & Luyster, R. J. (2016). The integrity of lexical acquisition mechanisms in autism spectrum disorders: A research review. *Autism Research*, *9*, 810–828.

Bal, V. H., Katz, T., Bishop, S. L., & Krasileva, K. (2016). Understanding definitions of minimally verbal across instruments: Evidence for subgroups within minimally verbal children and adolescents with autism spectrum disorder. *Journal of Child Psychology and Psychiatry*, *57*, 1424–1433.

Baldwin, D. A. (1993). Early referential understanding: Infants' ability to recognize referential acts for what they are. *Developmental Psychology*, *29*, 832.

Baldwin, D. A., & Moses, L. J. (2001). Links between social understanding and early word learning: Challenges to current accounts. *Social Development*, *10*, 309–329.

Baron-Cohen, S., Baldwin, D. A., & Crowson, M. (1997). Do children with autism use the speaker's direction of gaze strategy to crack the code of language? *Child Development*, *68*, 48–57.

Bean Ellawadi, A., & McGregor, K. K. (2016). Children with ASD can use gaze to map new words. *International Journal of Language & Communication Disorders*, *51*, 212–218.

Billstedt, E., Carina Gillberg, I., & Gillberg, C. (2007). Autism in adults: Symptom patterns and early childhood predictors. Use of the DISCO in a community sample followed from childhood. *Journal of Child Psychology and Psychiatry*, *48*, 1102–1110.

Bion, R. A., Borovsky, A., & Fernald, A. (2013). Fast mapping, slow learning: Disambiguation of novel word–object mappings in relation to vocabulary learning at 18, 24, and 30 months. *Cognition*, *126*, 39–53.

Bloom, P., & Markson, L. (1998). Capacities underlying word learning. *Trends in Cognitive Sciences*, *2*, 67–73.

Carey, S., & Bartlett, E. (1978). Acquiring a single new word. *Proceedings of the Stanford Child Language Conference*, *15*, 17–29.

Clark, E. V. (1990). On the pragmatics of contrast. *Journal of Child Language*, *17*, 417–431.

Condouris, K., Meyer, E., & Tager-Flusberg, H. (2003). The relationship between standardized measures of language and measures of spontaneous speech in children with autism. *American Journal of Speech-Language Pathology, 12*, 349–358.

Dunn, L. M., & Dunn, D. M. (2007). *Peabody picture vocabulary test: Fourth edition*. San Antonio, TX: Pearson.

Eigsti, I. M., de Marchena, A. B., Schuh, J. M., & Kelley, E. (2011). Language acquisition in autism spectrum disorders: A developmental review. *Research in Autism Spectrum Disorders*, *5*, 681–691.

Gathercole, S. E., Willis, C. S., Baddeley, A. D., & Emslie, H. (1994). The children's test of nonword repetition: A test of phonological working memory. *Memory*, *2*, 103–127.

Gliga, T., Elsabbagh, M., Hudry, K., Charman, T., & Johnson, M. H. (2012). Gaze following, gaze reading, and word learning in children at risk for autism. *Child Development*, *83*, 926–938.

Golinkoff, R. M., Hirsh-Pasek, K., Bailey, L. M., & Wenger, N. R. (1992). Young children and adults use lexical principles to learn new nouns. *Developmental Psychology*, *28*, 99.

Hani, H. B., Gonzalez-Barrero, A. M., & Nadig, A. S. (2013). Children's referential understanding of novel words and parent labeling behaviors: Similarities across children with and without autism spectrum disorders. *Journal of Child Language*, *40*, 971–1002.

Henderson, L., Powell, A., Gareth Gaskell, M., & Norbury, C. (2014). Learning and consolidation of new spoken words in autism spectrum disorder. *Developmental Science*, *17*, 858–871.

Howlin, P., Magiati, I., & Charman, T. (2009). Systematic review of early intensive behavioral interventions for children with autism. *American Journal on Intellectual and Developmental Disabilities*, *114*(1), 23–41.

Hus, V., Gotham, K., & Lord, C. (2014). Standardizing ADOS domain scores: Separating severity of social affect and restricted and repetitive behaviors. *Journal of Autism and Developmental Disorders*, *44*, 2400–2412.

Hus, V., Maye, M., Harvey, L., Guthrie, W., Liang, J., & Lord, C. (2011). *The adapted ADOS: Preliminary findings using a modified version of the ADOS for adults who are nonverbal or have limited language*. Poster presented at the International Meeting for Autism Research, San Diego, CA.

Kaufman, N. R. (1995). *The Kaufman speech praxis: Test for children*. Detroit, MI: Wayne State University Press.

Lord, C., Rutter, M., DiLavore, P. C., Risi, S., Gotham, K., & Bishop, S. (2012). *Autism diagnostic observation schedule–Second edition (ADOS-2)*. Los Angeles: Western Psychological Services.

Luyster, R., & Lord, C. (2009). Word learning in children with autism spectrum disorders. *Developmental Psychology*, *45*, 1774.

Markman, E. M., & Wachtel, G. F. (1988). Children's use of mutual exclusivity to constrain the meanings of words. *Cognitive Psychology*, *20*, 121–157.

Markman, E. M., Wasow, J. L., & Hansen, M. B. (2003). Use of the mutual exclusivity assumption by young word learners. *Cognitive Psychology*, *47*, 241–275.

McDuffie, A., Kover, S. T., Hagerman, R., & Abbeduto, L. (2013). Investigating word learning in fragile X syndrome: A fast-mapping study. *Journal of Autism and Developmental Disorders*, *43*, 1676–1691.

McDuffie, A., Yoder, P., & Stone, W. (2006). Fast-mapping in young children with autism spectrum disorders. *First Language*, *26*, 421–438.

Miller, J. F., Andriacchi, K., & Nockerts, A. (2011). *Systematic analysis of language transcripts*. Madison, WI: SALT Software.

Mundy, P., Sigman, M., & Kasari, C. (1990). A longitudinal study of joint attention and language development in autistic children. *Journal of Autism and Developmental Disorders, 20*, 115–128.

Munson, J., Dawson, G., Sterling, L., Beauchaine, T., Zhou, A., Koehler, E., . . . Abbott, R. (2008). Evidence for latent classes of IQ in young children with autism spectrum disorder. *American Journal on Mental Retardation*, *113*, 439–452.

Norbury, C. F., Griffiths, H., & Nation, K. (2010). Sound before meaning: Word learning in autistic disorders. *Neuropsychologia*, *48*, 4012–4019.

Pickles, A., Anderson, D. K., & Lord, C. (2014). Heterogeneity and plasticity in the development of language: A 17-year follow-up of children referred early for possible autism. *Journal of Child Psychology and Psychiatry*, *55*, 1354–1362.

Preissler, M. A., & Carey, S. (2005). The role of inferences about referential intent in word learning: Evidence from autism. *Cognition*, *97*, B13–B23.

Rice, M. L., Buhr, J. C., & Nemeth, M. (1990). Fast mapping word-learning abilities of language-delayed preschoolers. *Journal of Speech and Hearing Disorders*, *55*, 33–42.

Roid, G. H., Miller, L. J., Pomplun, M., & Koch, C. (2013). *Leiter international performance scale: Third edition*. Wood Dale, IL: Stoelting.

Rutter, M., Le Couteur, A., & Lord, C. (2003). *Autism diagnostic interview – Revised*. Los Angeles, CA: Western Psychological Services.

Sennott, S. C., Light, J. C., & McNaughton, D. (2016). AAC modeling intervention research review. *Research and Practice for Persons with Severe Disabilities*, *41*, 101–115.

Tabachnick, B. G., & Fidell, L. S. (2007). *Using multivariate statistics* (5th ed.). New York: Allyn and Bacon.

Tager-Flusberg, H., & Kasari, C. (2013). Minimally verbal school-aged children with autism spectrum disorder: The neglected end of the spectrum. *Autism Research, 6*, 468–478.

Tomasello, M., & Barton, M. E. (1994). Learning words in nonostensive contexts. *Developmental Psychology*, *30*, 639.

Venker, C. E., Kover, S. T., & Weismer, S. E. (2016). Brief report: Fast mapping predicts differences in concurrent and later language abilities among children with ASD. *Journal of Autism and Developmental Disorders*, *46*, 1118–1123.

Wilkinson, K. M. (2005). Disambiguation and mapping of new word meanings by individuals with intellectual/developmental disabilities. *American Journal on Mental Retardation*, *110*, 71–86.

Wilkinson, K., & Green, G. (1998). Implications of fast mapping for vocabulary expansion in individuals with mental retardation. *Augmentative and Alternative Communication*, *14*, 162–170.