Journal of Autism and Developmental Disorders
https://doi.org/10.1007/s10803-020-04687-x

BRIEF REPORT

Brief Report: Children on the Autism Spectrum are Challenged by Complex Word Meanings

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Abstract
The current work suggests that two factors conspire to make vocabulary learning challenging for youth on the Autism spectrum: (1) a tendency to focus on specifics rather than on relationships among entities and (2) the fact that most words are associated with distinct but *related* meanings (e.g. baseball *cap*, pen *cap,* bottle *cap*). Neurotypical (NT) children find it easier to learn multiple related meanings of words (*polysemy*) in comparison to multiple unrelated meanings (*homonymy*). We exposed 60 NT children and 40 verbal youth on the Autism spectrum to novel words. The groups' performance learning homonyms was comparable, but unlike their NT peers, youth on the spectrum did not display the same advantage for learning polysemous words compared to homonyms.

Keywords Language · Communication · Linguistics · Vocabulary · Polysemy

Introduction

Children on the Autism spectrum are recognized to commonly face delays and ongoing challenges in language learning (Henry et al. 2018; Kim et al. 2014). Differences related to joint attention and social skill contribute to these challenges (Kuhl et al. 2005; Mundy et al. 1990; Paul 2003), and language therapies therefore tend to focus on improving these abilities (Schreibman 2000; Paul 2003). Yet the emphasis on the impact of social skills overlooks the potential role of differential cognitive effects on language development in those with ASD (cf. Eigsti and Schuh 2016; Schuh et al. 2016; Ozonoff and McEvoy 1994). We are particularly interested in the fact that individuals on the spectrum tend to have difficulty identifying relationships among individual instances to form more general categories. For instance, Plaisted et al. (1998) demonstrated that children on the Autism spectrum were less successful than NT children at identifying new instances of a category of dot patterns, and instead tended to treat similar dot patterns as entirely novel. Relatedly, children on the Autism spectrum show a reduced ability to sort by gestalt principles (Brosnan et al. 2004), and they have been found to generalize categories more easily on the basis of rule-based strategies involving a single dimension (such as shape) than on the basis of multiple dimensions ("red and round") (Klinger and Dawson 2001; Minshew et al. 1992; Rutherford and McIntosh 2007). Rather than attending to relationships and generalizations, children on the spectrum tend to devote enhanced attention to perceptual distinctions, resulting in a greater tendency to treat similar instances as entirely new (Molesworth et al. 2005; Mottron et al. 2006; Mottron and Morasse 2001). This tendency to focus on distinctions over generalizations potentially has broad implications. For instance, learning to predict upcoming events may require us to recognize that a current series of events relates to events we experienced previously. The finding that individuals on the spectrum find it more challenging to make predictions (Sinha et al. 2014) may in part stem from problems detecting similarities and relationships across experiences.

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s10803-020-04687-x) contains supplementary material, which is available to authorized users.

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Published online: 18 September 2020

In language, the ability to recognize relatedness among individual instances in order to form generalizations is essential (Goldberg 2019; Tomasello 2009). Consider the simple case of how individual words are pronounced. Different speakers will pronounce the same word differently depending on their gender, their size, and their dialect, and each person's pronunciation will additionally vary, depending on speech rate and context (Elman 2009). Although listeners only hear individual instances, we must be ready to recognize a new instance as a member of the same word category in order to recognize it. Similarly, the ability to interpret utterances in which familiar words are used in new ways (e.g., *Daddy laughed me off the couch*) requires that language learners generalize across utterances and learn the patterns, or *grammatical constructions* of their languages (Goldberg 2019). One small study compared 7-year-old NT children with youth on the Autism spectrum (ages 8–13) on their ability to generalize from examples of a newly learned novel grammatical construction to new instances of the construction (Johnson et al. 2012). While both groups displayed comparable above-chance memory of the original examples, the children on the spectrum lagged far behind in their ability to interpret new instances. Additional support for the idea that challenges in generalization may affect the overall language profile of children on the Autism spectrum comes from a tendency to rely more on stored verbatim utterances, and show less productivity in figurative language (Brosnan et al. 2004; Molesworth et al. 2005; Plaisted et al. 1998; Rutherford and McIntosh 2007). We here explore the idea that challenges in recognizing relationships across instances may affect vocabulary learning in individuals on the Autism spectrum.

Learning the meanings of words is critical for successful communication and classroom learning (Hawa and Spanoudis 2014). An under-appreciated challenge involved stems from the fact that a single label is frequently associated with multiple meanings (Piantadosi et al. 2012). Homonyms are words that are associated with two or more unrelated meanings, such as *bat*, which can refer to either a flying mammal or a wooden stick. Vastly more common are polysemous words, which are associated with distinct but *related* meanings (Britton 1978; Brocher et al. 2017; Dautriche et al. 2016; Durkin and Manning 1989; Fellbaum 2010; Fillmore and Atkins 2000; Floyd and Goldberg 2020; Geeraerts 1993; Lakoff 1987; 2012; Navigli and Ponzetto 2012; Srinivasan et al. 2019). For example, *cap* can be used to label a baseball cap, a bottle cap, or a pen cap, each of which involves a distinct shape, material, and purpose, but all of which refer to something that tightly covers something else. While only about 4% of English words are homonymous, the percentage of polysemous words is an order of magnitude greater (40–80%) (Dautriche et al. 2016; Fellbaum 2010; Rodd et al. 2002).

Recent work has found that neurotypical (NT) children and adults find it relatively easy to learn polysemous word meanings and can often interpret a new related meaning upon a single encounter (Floyd and Goldberg 2020; Srinivasan et al. 2019). In a direct comparison in which NT participants were exposed to several novel polysemous words or several novel homonyms, both 4½–7 year-olds and adults displayed a marked advantage in learning polysemy over homonymy, and both NT groups demonstrated strong retention of the polysemous word meanings after a week delay (Floyd and Goldberg 2020). This finding motivates the current work, which asks whether youth on the Autism spectrum exhibit an equivalent polysemy over homonymy advantage in word learning.

Evidence that challenges in generalization affect vocabulary learning in children on the Autism spectrum comes from research on the "shape bias," which is the well-documented tendency for word-learners to extend a word that refers to a solid object for use with other solid objects that share the same shape (Landau et al. 1988; Smith et al. 2002). Evident in neurotypical by the age of 2, the bias to privilege shape over color, texture or size has been found to be absent in 3 and 4 year-olds on the Autism spectrum (Tek et al. 2008). At the same time, there is a good deal of individual variation in the use of a shape bias among children with ASD (Tovar et al. 2019), and a longitudinal study with more participants has found that highly verbal participants on the spectrum do eventually develop it (Hartley et al. 2019; Potrzeba et al. 2015). We suggest that the delay in learning the shape bias may stem from individuals' greater challenge generalizing across exemplars.

There is evidence that individuals on the Autism spectrum make less spontaneous use of polysemous words than neurotypical adults (de Villiers et al. 2013), and can find it challenging to generalize phrases to flexibly and appropriately apply them in new contexts (Brosnan et al. 2004; Mottron and Morasse 2001). For instance, it may be harder to understand what *boiling mad* means if the metaphorical relationship between heat and anger is not appreciated. To the extent that youth on the spectrum privilege differences between concepts over relationships among them, we predict that the learning advantage for polysemy over homonymy, evident in neurotypicals, will be attenuated in this group. A baseball cap and a bottle cap differ, after all, in shape, material, size, and function, and these differences may interfere with the recognition of their related covering functions.

To summarize, a narrower focus of attention and concomitant challenges forming generalizations may affect vocabulary learning, given that a plurality of words involve complex constellations of related meanings. Therefore, we hypothesize that youth on the Autism spectrum will not benefit from the same polysemy over homonymy advantage

in word learning that has been found in neurotypical word learners (Floyd and Goldberg 2020).

Experiment

Design, sample sizes, age ranges, and basic analyses were preregistered at AsPredicted.org (see Appendix). Each child was exposed to 4 novel words in a polysemy condition and 4 novel words in a homonymy condition (8 words in total). Each word was assigned 3 distinct meanings, represented by distinct objects, which were either visually related (polysemy) or unrelated (homonymy) to one another (see Fig. 1 for example stimuli).

After brief exposure to the novel words and images of objects, along with a larger set of distractor images (see Fig. 2), children were tested on how accurately they identified the 3 target meanings for each novel word, from sets that additionally included 5 previously witnessed distractors. Children who were available were recruited again after a week delay and retested on the same task, without re-exposure.

Methods

Participants

We recruited 40 youth on the Autism spectrum ages 7–14 ($M = 11.68$ years, $SD = 1.82$; 21 male) from various schools and extracurricular programs. Each had received a clinical or school diagnosis of ASD, and were reported to be "verbal" or "highly verbal" by a parent or guardian. Thirty-six children in this group also took the PPVT-IV, a measure of receptive vocabulary to determine the age equivalencies of their vocabulary. (The order of the main and PPVT tasks were counterbalanced.) 60 neurotypical (NT) children, ages 5–12 were also tested ($M = 7.74$ years, $SD = 1.67$, 33 male). NT children were recruited through a local summer program. All children were given a book for participation.

Novel Words

The 4 polysemous novel words were constructed such that one "prototypical" meaning contained two distinguishing visual features: one feature was shared by a second meaning, and the second feature was shared by a third meaning.

Fig. 1 Top: sample stimuli in **polysemy** condition with center image being prototype. Bottom: sample stimuli in **homonymy** condition

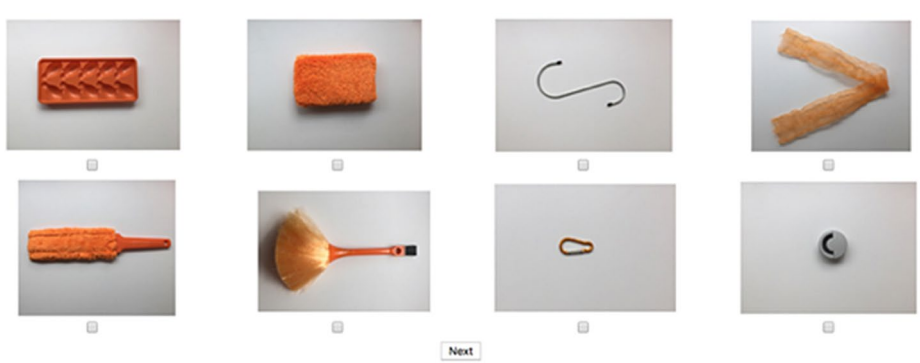

Fig. 2 Stimuli used in sample test trial, including 3 target images and 5 distractors

That is, no single feature held of all three meanings that could distinguish them from distractors. Stimuli were created in this way in order to be more ecologically valid, since a word's meanings typically do not share necessary or sufficient features (Jackendoff 1983; Fillmore and Atkins 2000; Lakoff 1987).

Exposure

Each participant was exposed to a total of 24 meanings across the polysemy condition (4 words, 3 senses apiece) and homonymy condition (4 words, 3 senses apiece), and 40 distractor images. The 8 novel word labels, e.g., *kaisee*, *veebo*, obeyed English phonotactic constraints. Each condition involved 2 exposure videos, containing a randomized stream of 16 novel objects, presented one at a time. Each 2-min video included 2 novel words and their associated 3 meanings as well as 10 distractor images; three of the six novel meanings were labelled by one word ("This is a kaisee"), and 3 other new novel objects were labelled by a second word. All images were witnessed once, except the "prototypical" object, which was seen twice (exposure matched across conditions). When a distractor was on screen, a brief tone instead of a label was played. The only difference between the homonymy and polysemy conditions was whether the novel words were assigned 3 related meanings (polysemy) or 3 unrelated meanings (homonymy). The order of conditions was counterbalanced across participants, and pairings between labels and novel object sets were also counterbalanced.

Test

On each trial, children saw a display of 8 images including 3 target senses of a word and 5 distractors that had been witnessed during the same exposure video. They were then asked, for example, to "Pick three kaisees" (the order of the 4 novel words within each condition was counterbalanced). Children were tested in a quiet area and wore noise-blocking headphones. The experiment was displayed on a monitor. Children selected answers using a wireless mouse, except if unable to operate it, in which case the child indicated options by pointing.

Results

Instead of matching the ASD group with NT children by chronological age, which can vary widely from developmental age in youth on the spectrum, we matched the two groups on performance in the comparison task (the homonymy condition). This comparison was not predicted to differ by group, and did not (Welch two-sample *t* test, $t(87.01) = 0.33$, $p = 0.74$). Bootstrapped 95% confidence intervals on homonymy performance was above chance for both samples (1.125, see Appendix for calculation of chance; ASD sample: $M = 1.47$, 95% CI [1.33–1.59]; NT sample: $M = 1.44$, 95% CI [1.34–1.53]). The performance in the homonymy condition allowed us to confirm that both groups were equally able to follow instructions and remember unrelated pairings of names and objects. Since a robust polysemy over homonymy advantage has been found in NT adults and children (ages 4–7) in prior work (Floyd and Goldberg 2020), the choice to test older youth on the spectrum was conservative: that is, the fact that the AS children were older than the current NT group is not likely responsible for the relative lack of polysemy over homonymy advantage in this group, who were matched on performance in the homonymy condition.

As preregistered, we entered the average accuracy per subject for each condition into separate paired *t*-tests within each group (NTs and Autism spectrum). As predicted, we found that NT participants performed significantly better in the polysemy condition than the homonymy condition ($t(59) = 5.56$, $p = 6.77e - 07$). Critically, the group on the spectrum showed no difference between conditions ($t(39) = 0.39$, $p = 0.69$). These results were confirmed with secondary preregistered analyses using mixed effect models (see Appendix). To ensure that the polysemy advantage was not solely detected in the NT population due to a difference in sample size, we also subsampled 40 NT participants closest to the 40 ASD participants in homonymy performance using nearest-neighbor matching, and the result was again confirmed: the 40 NT participants show a significant polysemy advantage $t(39) = 5.25$, $p = 5.72e - 06$, while the ASD participants do not $t(39) = 0.39$, $p = 0.69$ (for further details see Appendix).

Nineteen NT children and 20 youth on the spectrum were available after a week delay and were retested on the same test trials in the same order, without any additional exposure (see Fig. 3). We again found that performance in the polysemy condition differed significantly from homonymy for the NT group ($t(18) = 3.22$, $p = 0.005$). Youth on the Autism spectrum showed marginally better accuracy in polysemy over homonymy at the second time point ($t(19) = 1.72$, $p = 0.10$). However, the marginal advantage in the ASD group was not reliable when controlling for items and subjects using multilevel modeling ($\beta = 0.16$, $t = 0.93$, $p = 0.39$), while the NT polysemy advantage was robust ($\beta = 0.53$, $t = 3.21$, $p = 0.01$).

The current results suggest that youth on the spectrum face an ongoing challenge: while TD performance in polysemy increased slightly with age ($\beta = 0.11$, $t = 2.83$, $p = 0.01$), we found no evidence of an increase with age in the ASD group using the same preregistered analysis ($\beta = 0.01$, $t = 0.26$, $p = 0.79$). The challenge in learning complex meanings is not likely due to failure to learn words with

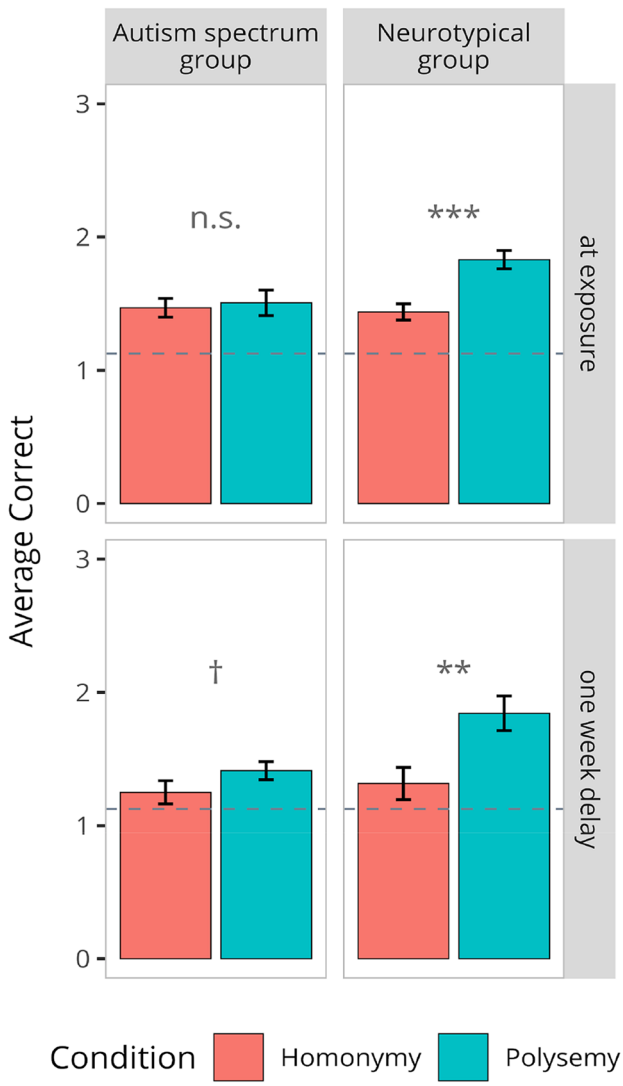

Fig. 3 Top row, NT children and children on the spectrum showed equivalent, above-chance accuracy on novel homonyms (pink). While NT children were significantly more accurate on polysemes, children on the spectrum displayed no difference (blue). Bottom row, performance after 1-week delay shows same pattern of results

single meanings: of the 36 ASD participants tested on the vocabulary measure, their vocab-equivalent age was greater than the NT children's chronological age (ASD vocab age equivalent: $M = 10.1$ years, $SD = 5.07$ *vs.* $M = 7.74$, $SD = 1.67$; $t(94) = 3.33$, $p = 0.001$).

Discussion

Neurotypical children and adults find it much easier to learn and remember related meanings of a word compared to unrelated meanings (Floyd and Goldberg 2020). The current results replicate this polysemy over homonymy advantage for NT children in a new within-subjects paradigm through exposure to 4 polysemous and 4 homonymous novel words, with three distinct meanings apiece. Notably, the ASD and NT groups showed equivalent, above-chance performance in the homonymy condition, demonstrating comparable understanding of the task and attention level. But strikingly, the youth on the Autism spectrum failed to show the same robust polysemy over homonymy advantage enjoyed by their NT peers. Since a plurality of words are polysemous in natural languages, this finding predicts vocabulary learning to be much harder for individuals on the Autism spectrum. While deficits in social skill and joint attention constitute the focus of many interventions aimed at improving communication and language skills in this population (Paul 2003; Mottron et al. 2006; Rutherford and McIntosh 2007), the current work emphasizes that learning to understand and use words in contextually appropriate ways may be compounded by challenges in forming generalizations.

To summarize, NT children find it relatively easy to learn that *glasses* can mean both "drinking cups made of glass" and "eye-glasses" because of the relationship between the two meanings. But children on the spectrum are not advantaged in the same way by the relationships between distinct meanings; they may find it no easier than learning that glasses mean "eye-glasses" and "porcelain mugs." A recognition of the challenge that polysemous words present to youth on the Autism spectrum may be useful for interventions aimed at improving communication skills in this group. In particular, support may be needed for youth on the Autism spectrum to recognize that a word witnessed in a particular context with a particular meaning can also be used in a different context with a related but distinct meaning.

Acknowledgments We thank the Cognitive Science program at Princeton University for funding the work, and Camp Akeela, Woods Services, Rock Brook School, Katherine Thomas School, and Princeton Speech and Language for help with recruitment.

Author Contributions SF and AEG contributed to the project conceptualization. All authors contributed to study design. SF and CJ contributed to data collection and analysis. All authors contributed to the writing of the manuscript.

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