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SHORT REPORT

Do focused interests support word learning? A study with autistic and nonautistic children

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Abstract

Although focused interests are often associated with a diagnosis of autism, they are common in nonautistic individuals as well. Previous studies have explored how these interests impact cognitive, social, and language development. While some research has suggested that strong interests can detract from learning (particularly for autistic children), newer research has indicated that they can be advantageous. In this preregistered study, we asked whether focused interests support word learning in 44 autistic children and a vocabulary-matched sample of 44 nonautistic children (mean ages 58 and 34 months respectively). In a word-learning task administered over Zoom, children were exposed to an action labeled by a novel word. The action was either depicted by their focused interest or by a neutral image; stimuli were personalized for each child. At test, they were asked to identify the referent of the novel word, and their eye gaze was evaluated as a measure of learning. The preregistered analyses revealed an effect of focused interests, and post-hoc analyses clarified that autistic children learned the novel word in both the focused interest and neutral conditions, while nonautistic children only showed evidence of learning in the neutral condition. These results suggest that focused interests are not disruptive for vocabulary learning in autism, and thus they could be utilized in programming that supports early language learning in this population.

Lay Summary

Although focused interests are often associated with a diagnosis of autism, they are common in nonautistic individuals as well. Previous studies have explored how these interests impact cognitive, social, and language development. While some research has suggested that strong interests can detract from learning (particularly for autistic children), newer research has indicated that they can support learning. In this study, we asked whether focused interests support word learning in 44 autistic children and 44 nonautistic children with similar language skills (average ages 58 and 34 months respectively). In an online task, children were taught a new word for an action. The action was either demonstrated by their focused interest or by a neutral image. At test, they were asked to identify the meaning of the new word. Results indicated that autistic children learned the word in both the focused interest and neutral conditions, while nonautistic children only learned in the neutral condition. These results suggest that focused interests could be utilized for supporting early language learning in children on the autism spectrum.

KEYWORDS
autism, interests, language, verbs, word learning

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INTRODUCTION

Young children often show focused interests (e.g., dinosaurs, birds, or Pokémon), which can be considered "fascinations with particular categories of objects or activities", wherein children may "display a passionate, sometimes bordering on obsessive, attraction to items in their interest category" (DeLoache et al., 2007, p. 1579). Focused interests have been observed in girls and boys (Alexander et al., 2008) and are reported in 30% to 50% of preschool children (Alexander et al., 2008; DeLoache et al., 2007). Strong interests have a number of advantages for learning, including increased knowledge, attention, recognition, and recall (Alexander et al., 2008; Hidi, 1990; Renninger, 1992; Renninger & Wozniak, 1985). Previous findings have also suggested that strong interests are positively associated with nonverbal cognition and language abilities (Alexander et al., 2002; Johnson et al., 2004; Johnson & Eilers, 1998). Some researchers have additionally considered the value of strong interests for language learning in young children: children's interest in an area predicts word knowledge (Mani & Ackermann, 2018) and performance in a word-learning task (Ackermann et al., 2020; Ackermann et al., 2023). Ackermann et al. (2020) taught 30-month-olds new nouns for objects in four different categories (animals, clothes, vehicles, and drinks); for each category, they obtained parent ratings on whether it was of high or low child interest. Nouns in high-interest categories were learned better than nouns in low-interest categories, and the researchers concluded that personal interest may scaffold language learning. These results are broadly consistent with other word-learning studies in even younger 24-month-old children, indicating that higher levels of existing word knowledge in a category facilitates learning new words in that same semantic category (Borovsky et al., 2016).

The implications of focused interests for learning have also been extensively considered in the development of individuals on the autism spectrum. "Restricted and repetitive interests" are included as one of the diagnostic features of Autism Spectrum Disorder (APA, 2013), and strong interests are experienced by the vast majority of autistic individuals (Grove et al., 2018; Klin et al., 2007; Nowell et al., 2021; Spiker et al., 2011). Although the intensity of interests may be stronger in autistic individuals than in people who do not have autism (Anthony et al., 2013; Burrows et al., 2021; Larose et al., 2021), the number and topic of interests may be similar (Anthony et al., 2013), including television, animals, construction, and art (Nowell et al., 2021).

There remains considerable debate over whether these interests are disruptive versus adaptive for cognitive, social, and daily functioning in individuals on the autism spectrum. Strong interests are seen by some caregivers and professionals as interfering (Anthony et al., 2013; Nowell et al., 2021) and requiring treatment (e.g., Carter et al., 2020). Indeed, some research has suggested that strong interests *can* distract individuals from attending to information in the environment. In a gaze-tracking study, Sasson and Touchstone (2013) reported that autistic preschoolers prioritized attention to images representing strong interests over attention to faces; the nonautistic sample did not show this pattern. Other research has suggested that depictions of strong interests can also distract nonautistic children from social information (Sasson et al., 2011; Ambarchi et al., 2022; we note that previous literature has often referred to these study samples as "typically developing", although here we are choosing to use the term "nonautistic" in order to avoid ableist language; Bottema-Beutel et al., 2021). It is noteworthy, though, that these studies have pitted attention to social cues *against* focused interests, rather than harnessing focused interests to scaffold attention. Accordingly, strength-based approaches view these interests as tools for learning. Patten Koenig and Hough Williams (2017) interviewed adults on the autism spectrum and learned that focused interests were experienced as strengths that helped (rather than hindered) daily functioning and played an important role in managing anxiety. Many of the adults were engaged in vocational and avocational pursuits surrounding their focused interests (see also Chiodo et al., 2017).

The question of whether focused interests can scaffold learning for autistic individuals has received the most attention for social communication skills. Consensus generally affirms that focused interests can effectively be harnessed to support social communication (e.g., Boyd et al., 2007; Dunst & Hamby, 2016; Gunn & Delafield-Butt, 2016; Harrop et al., 2019; Ninci et al., 2019; Sivaraman & Fahmie, 2018). Similarly, there is evidence of positive collateral effects on self-image, mood, and attention (Vismara & Lyons, 2007; Winter-Messiers, 2007). Moreover, some research has also focused on a potential link between strong interests and language skills for young autistic children. For instance, Jacques et al. (2018) found that children on the autism spectrum were more inclined than their nonautistic peers to show strong interests in language- and literacy-related objects or activities (e.g., picture dictionary, books, magnetic letters); in other work, similar strong interests were found to facilitate communication and language skills in hyperlexic autistic children (Ostrolenk et al., 2023). Larose et al. (2021)—in their development of a parent survey capturing the strengths and interests of autistic preschoolers—also reported that, for young autistic children, strong interests were perceived by parents to support language and literacy development. In a recent study of interests and word learning in a small sample of school-age autistic individuals, Rothwell et al. (2023) found that words reported to be in a high interest category (i.e., animals) were retained better than those of low interest (i.e., objects) but only for 5-min retention tests; apparent memory

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consolidation for the object category meant that the condition effect had diminished by 24 hours later.

There are several reasons why this link between strong interests and language skills is a particularly notable connection. First, autistic children often experience language delays (e.g., Nitzan et al., 2022; Tager-Flusberg, 2016), reduced vocabulary size, and slowed progression of morphology and grammar (e.g., Charman et al., 2003; Luyster et al., 2007; Pickles et al., 2014). As autistic children age, there is wide variability in language outcomes, with a substantial minority of individuals remaining nonspeaking through adulthood (Pickles et al., 2014; Tager-Flusberg & Kasari, 2013). Early language development predicts language outcomes, and the most substantial language gains seem to happen before the age of 8–10 years (Bal et al., 2018; Pickles et al., 2014). Therefore, identifying strategies to support foundational language skills is a priority; focused interests may offer a potential strategy for scaffolding this essential domain.

Here, we aim to more directly address the question of whether invoking a child's focused interest results in more robust language learning, specifically, word learning, than invoking "neutral" items for children on the autism spectrum, as well as their nonautistic peers. Unlike research on how children learn about the interests themselves (e.g., Ackermann et al., 2020), the current study presents word meanings that are unrelated to the interest; the interests are used only to depict a novel action. Importantly, this allows us to explore how interests could be leveraged to promote generalized learning (i.e., not just about concepts that are related to the interest). For this reason, we used novel verbs as the target words to be learned, which could be depicted using an object that invoked the child's interest. Using a quasi-experimental design, in which preschool-aged children were taught a new verb for an action, we recorded child gaze to measure their learning of the new verb; novel verb learning studies have been successfully used with autistic children in this age group (e.g., Horvath et al., 2018; Naigles et al., 2011). In contrast to studies that assign neutral and high-interest stimuli universally to all children (e.g., Rothwell et al., 2023; Sasson et al., 2011), we personalized the stimuli to reflect each child's own preferences. In accordance with the emerging evidence supporting focused interests as potential learning tools, we hypothesized that children in both groups would look more to the target when it was taught using their focused interest than when it was taught using a neutral item.

METHODS

Participants

Participants were recruited via laboratory databases, internet/social media, word-of-mouth and the SPARK autism research registry (Feliciano et al., 2018). A screening questionnaire was used to determine eligibility based on parent report. Inclusion criteria for all participants were: birth at ≥37 weeks gestation; hears English more than 70% of the time; normal/corrected-to-normal vision; normal hearing; has access to computer/tablet with Zoom software and a stable internet connection.

Additional inclusion criteria for the autism group included a Social Communication Questionnaire (SCQ; Rutter et al., 2003) total score of equal to or greater than 12 (although the standard cutoff for the SCQ is 15 for children ≥4 years and 12 for children below this age, see Corsello et al., 2007, we applied the lower cutoff to all children), a current medical/educational diagnosis of ASD, and a chronological age of 36–71 months.

Additional inclusion criteria for the nonautistic group included a SCQ score less than 12 and a chronological age of 24–59 months (younger children were targeted to facilitate matching on language ability, because most young autistic children have language delays). Nonautistic participants were excluded if they had a diagnosis of ASD, Language Impairment, Intellectual Disability, or a genetic disorder, or if any family members were diagnosed with ASD. In this way, our use of the term "nonautistic" for the comparison sample is meant to denote that these children did not experience autism nor any of the listed conditions, which commonly co-occur with autism.

Based on the above inclusion/exclusion criteria for participation in the study, the initial sample who completed the study consisted of 125 children. However, after participation in the study, some children were excluded from analyses. In order to be included in the final analysis sample, participants in the autism group required diagnostic confirmation by our study psychologist (more information below in *Procedure*). Five children in the autism group did not receive diagnostic confirmation based on the DSM-5 criteria (for instance, because they showed reciprocity and nonverbal communication typical for nonautistic children of their age) and were excluded from analyses.

Seven trials from 7 autistic participants and 5 trials from 5 nonautistic participants were then excluded because parent report on the day of the study did not indicate the appropriate level of child focused interest in the images used for the experimental trials (see below). Next, trials were excluded for track loss (see below): 8 trials from autistic children and 2 trials from nonautistic children, as well as both trials from one nonautistic child who was excluded entirely from analysis.[1] This process left an interim sample of 60 autistic and 59 nonautistic

[1]As indicated in our preregistration, we planned to exclude children who did not complete both trials, because we were concerned that children who "fussed out" of one of the trials might differ systematically from those who did not (e.g., children who were overstimulated if their focused interest was presented first and did not sit through the second trial). All participants did sit through and complete both trials. However, after removing individuals for parent report of child interest on the day of study and for track loss, only one trial remained in the final analyses for some participants. Following a reviewer suggestion, we repeated the analyses on only children who contributed both trials; the patterns were the same. These post-hoc analyses are available on OSF.

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TABLE 1 Sample information.

	Autistic ($n = 44$)	Nonautistic ($n = 44$)
Age range in months	40–70	24–60
Mean age in months (SD)	58 (8)	34 (9)
MCDI3 score range	0–100	4–100
Mean MCDI3: number of words spoken (SD)	62 (31)	65 (29)
MCDI3 # children combining words[a]		
Not yet	1	—
Sometimes	10	3
Often	30	41
Mean Vineland Communication Domain Raw Score (SD)	25.50 (12.34)	27.61 (12.93)
Mean SCQ Score (SD)	19.26 (5.12)	5.20 (2.61)
Min-Max SCQ Score	13–33	0–11
Mean Interest in "focused interest" (SD)[b]	3.86 (0.46)	3.95 (0.21)
Mean Interest in "neutral interest" (SD)[b]	2.18 (0.81)	2.18 (0.87)
Race		
Asian	1	3
Black	1	0
Hispanic White	5	2
Non-Hispanic White	27	34
Hispanic or Non-Hispanic Other	7	5

Note: MCDI3 = MacArthur Bates Communicative Development Inventory 3 (Fenson et al., 2006). Vineland = Vineland Adaptive Behavior Scale 3rd ed. Parent/Caregiver Form (Sparrow et al., 2016). SCQ = Social Communication Questionnaire (Rutter et al., 2003).
[a]Data missing for 3 participants in autistic group.
[b]Per caregiver endorsement of the following statement: "My child is really interested in the above character/object" on a rating scale of 1 = Never; 2 = Rarely; 3 = Sometimes; 4 = Often.

children. However, preliminary analyses revealed that these two groups (autistic and nonautistic) differed significantly in spoken language ability as measured by expressive vocabulary on the MacArthur Bates Communicative Development Inventory 3, or MCDI3 (Fenson et al., 2006; autistic MCDI3 range 0–100, mean 46 words; nonautistic MCDI3 range 4–100, mean 71 words; $t(117) = 4.096$, $p < 0.0001$). Therefore, to ensure that our final groups did not significantly differ in vocabulary, which was stipulated in our preregistration, we used a bootstrap process with the bootmatch package (Mahr, 2023) in R, requiring a match within ±10 spoken words on the MCDI3.

This matching process resulted in a final sample of 44 children per group from 27 US states (autistic group: 35 boys, 9 girls; nonautistic group: 32 boys, 12 girls); the groups did not significantly differ in MCDI3 score ($t(86) = 0.44$, $p = 0.66$). The effect size (Cohen's d) for the difference between the matched groups on MCDI3 was 0.093, and the variance ratio was 0.93; following suggestions in Kover and Atwood (2013), we took these to be acceptably matched. Diagnostic groups differed significantly in age, as is common when groups are matched on language (autistic group: mean age 58 months (range = 40–70 months, $SD = 8$ months): nonautistic group: mean age 34 months (range = 24–60 months, $SD = 9$ months), $t(86) = 12.6$, $p < 0.0001$). See Table 1 for final sample information.[2]

Procedure

Procedures and analyses were pre-registered (https://osf.io/ra4un/). Study activities were approved by an Institutional Review Board. This was a remote study. All parent-report measures were collected via REDCap (Harris et al., 2009, 2019) and all "in person" portions were conducted and recorded via Zoom. A screening questionnaire determined eligibility for the study (described above) and additionally asked caregivers to identify and rank their child's three favorite interests (including toys/characters/topics; e.g., squirrels, Mickey Mouse, guitar). Caregivers whose children were eligible based on the criteria listed above were emailed the links to the electronic consent forms to review independently. A Zoom consent session was scheduled at the caregiver's convenience, and consent was then discussed via Zoom with the caregiver and any outstanding questions were answered. The caregiver was then asked to sign the consent forms electronically. After consent was complete, the experimenter and caregiver worked together in real time over Zoom to identify the best visual representation of the child's focused interest using Google Images.[3] The caregiver was also presented with images of other participants' focused interests to identify images that would be "neutral" for their child (i.e., an item that was familiar but toward which the child had no strong feelings). We aimed to reuse focused interest images as another participant's neutral image, but this was not always possible because we had to ensure that neutral images were truly neutral for a participant (and not unfamiliar or strongly preferred); 83% of focused interest images were able to be reused as another participant's neutral image. Focused and neutral interest images were paired for each participant based on animacy and size. If a participant had the

[2]As part of our post-hoc analyses, we repeated the analyses on the full group of autistic participants, including those with very low language scores who could not be matched to a nonautistic participant. The patterns were the same, and showed that in both conditions, children with higher vocabularies showed a stronger preference for the target. The analyses are available on OSF.
[3]Caregivers were also asked to complete the Survey of Favorite Interests and Activities (SOFIA; Smerbeck, 2017) to rate the child's behavior relative to their focused interests on a scale of 1 (never or not at all true) to 5 (very frequently or totally true). These results capture children's behavior and interests *in general*, not the specific interests used in the current study; consequently, these data were not used. We report on the SOFIA data elsewhere (Turner et al., n.d.).

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same focused interest as another participant, a different image depicting the interest was used.

Families were then scheduled for an online study visit. In advance of the study visit, parents were asked to complete questionnaires about their child, including the MCDI3 (Fenson et al., 2006) and the Vineland Adaptive Behavior Scales 3rd Edition Parent/Caregiver form (Sparrow et al., 2016). In advance of the study visit, participants were assigned to one of four condition sets, which counterbalanced assignment of focused versus neutral interest to novel verb (i.e., *kibbing*/*doking*) and trial order (focused interest presented in first or second trial). During the study visit, which was conducted on Zoom, the child sat in front of a computer or tablet screen to view the study videos. The child's gaze was recorded using Zoom during the study session. The experimenters asked the caregiver to ensure that the child was seated centrally in front of the screen and not to speak to the child during the videos.

Finally, although interests were collaboratively identified during the introductory informed consent call with the parents, we asked parents to confirm their child's interest on the day of data collection in order to measure whether a child's interest level had changed in the interim period. Therefore, at the end of the experimental session, caregivers were asked to attest to their child's level of interest in the images (focused interest and neutral) used during the study session on a scale of 1 (never) to 4 (often) for the following statement: My child is really interested in the above character/object. In order to be included in analysis, we required that, on the day of data collection, parents endorse that statement with a rating of "often" for the interest condition and a rating of "never," "rarely," or "sometimes" for the neutral condition. Caregivers were also asked to confirm that their child had not developed an aversion to either image in the past week. See Supplementary Materials Table A for the items used for each participant's focused and neutral interest condition.

Materials

During the remote, Zoom-based study visit, children participated in two verb-learning trials, one per condition, each including a training video and a test video (see Figure 1), without a pause between them. (Many verb-learning studies teach only one novel verb per condition, e.g., Dautriche et al., 2014; He & Lidz, 2017; Ma et al., 2023; Yuan & Fisher, 2009) Videos were structured identically for each child, but the images that appeared in them were individualized. Each training video was 24 s and presented an object/character completing an action. For one video, the object/character depicted the child's focused interest, which had been previously determined via caregiver report (as described above). In the other video, the object/character was of neutral interest to the child. Images had a clear background and were cropped to ~300 × 300 pixels.

Both training videos began with a Character Introduction phase, which presented the object/character as a still image in center screen, with a pre-recorded voice-over: "Wow, look at my friend! He/she/it is going to play a game with us today!" Then, in the Novel Word Introduction phase the object/character moved in a particular way 4 times; the narrator labeled the action using a novel word each time. The two actions were: (1) spinning, labeled "doking" (/dokɪŋ/); and (2) arcing, labeled "kibbing" (/kɪbɪŋ/). For instance, for objects spinning during the video, the narrator said, "Cool, he/she/it is doking! Ooh, he/she/it is doking. Wow, he/she/it is doking! How fun, he/she/it is doking!" Videos portraying an arcing motion were similarly described but using the word "kibbing." The phonological forms of the novel words were chosen because they are commonly used in novel verb learning studies (e.g., He & Lidz, 2017; Johnson & de Villiers, 2009) and were not being used in any other verb learning studies in the lab that these same children might also participate in. Audio was recorded by a female speaker of North American English in a child-directed register. Narrations used the most commonly associated gender pronoun for the object/character ("he", "she" or "it").

Immediately after each training video, a split-screen test video presented the object/character previously completing the doking/kibbing motion on one side of the screen; the other side depicted the same object/character completing a different motion not previously shown. First, during the Baseline phase (6 s), children viewed the two scenes side-by-side in silence. Then during the Query phase (2.5 s), the two scenes disappeared and were replaced with a centrally positioned spiral image serving as a central fixation, and children were asked, "where's doking/kibbing?" Then, during the Response phase (6 s), the two scenes reappeared in their original positions and children heard, "Find doking/kibbing." The assignment of the target/distractor action to the left or right side of the screen was counterbalanced across participants and trials.

Post-Visit confirmation, coding and analysis

After the study visit, diagnostic confirmation and gaze coding were completed by study staff. The process for diagnostic confirmation (our autistic sample was recruited on the basis of having of an existing ASD diagnosis) was based on "best practice" recommendations that autism assessment include developmental/language measures, parent report, direct observation of the child and DSM-5 criteria (e.g., Brian et al., 2019; Zwaigenbaum & Penner, 2018). Therefore, a licensed psychologist with advanced expertise in autism reviewed all available study information, including

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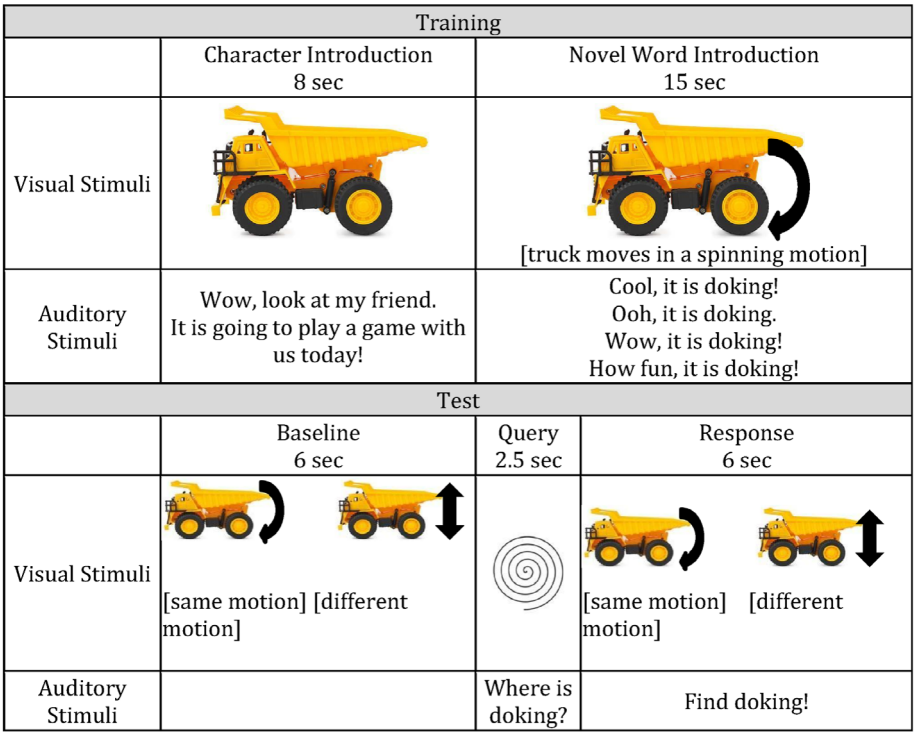


FIGURE 1 Schematic depiction of stimuli on one trial.

parent report instruments (e.g., SCQ, MCDI3, Vineland) and the recorded study session; based on this information, she completed a DSM-5 checklist attesting to diagnostic confirmation.

For gaze, three coders viewed the Zoom recordings and manually coded children's eye gaze during the test videos frame-by-frame at 30 frames/second in Adobe Premiere Pro software.[4] Coders were trained on practice videos until they achieved 95% agreement with the training standard, after which they coded independently. All coders were naive to the child's diagnostic status, what the child was seeing on screen, and which side displayed the target action. Coders indicated whether the child was looking "right," "left," "elsewhere" (away from screen but child's eyes are still visible), or "track loss" (child's direction of gaze is not visible, e.g., blinking, head turned). Although because this was an at-home study, participants' screen sizes and children's distance from the screen varied, we created the videos to have a large space between the "left" and "right" scenes to assist coders in distinguishing them. Inter-coder reliability on whether coders matched on their use of the four direction codes for each frame was calculated for 10% of the videos (based on previous literature; e.g., Naigles & Tovar, 2012; Abu-Zhaya et al., 2023; Delle Luche et al., 2015), each of which were coded by two coders, using the irr package v0.84.1 in R (Gamer & Lemon, 2019). Percent agreement for coder pairs for the autistic group ranged from 92% to 98% and Cohen's kappa from 0.89 to 0.95; for the nonautistic group, percent agreement ranged from 97% to 99% and Cohen's kappa from 0.91 to 0.99.

Following similar studies (e.g., Arunachalam & Dennis, 2019; Horvath et al., 2018), we planned to analyze children's eye gaze from 1 to 2.5 s of the Response phase, which was after children had heard the test query during the Query phase, and immediately at the offset of the second prompt to find the target during the Response phase. This window is appropriate because in similar studies it takes approximately 1 s for children to settle on a scene after a central fixation, and after approximately 2.5 s, children tend to shift gaze to the scene they had not previously been fixating. We binned the data into 100 ms bins (approximately 3 frames per bin) and empirical-logit transformed the proportion of looking to the target in each bin. This transformed data served as the dependent variable (Barr, 2008).

RESULTS

As noted above, before creating the final matched sample for analysis, we excluded trials for track loss. Specifically, we excluded trials on which 50% or more of the 6-second Response phase consisted of track loss, indicating that children were inattentive after the test

[4]Because frame rates vary slightly when videos are played on different devices with different internet connectivity, and so forth, we coded the videos using audio cues within each trial; by "restarting" the coding from each audio cue, we ensured that any lag that accumulated over the course of playing a video was reset at each critical time point and did not persist over the course of the entire video. The longest time period over which lag could have accumulated using this procedure was 2.5 seconds; spot-checking of several videos indicated that they rarely differed in frame length over this short time period, and if they did it was only by 1–2 frames.

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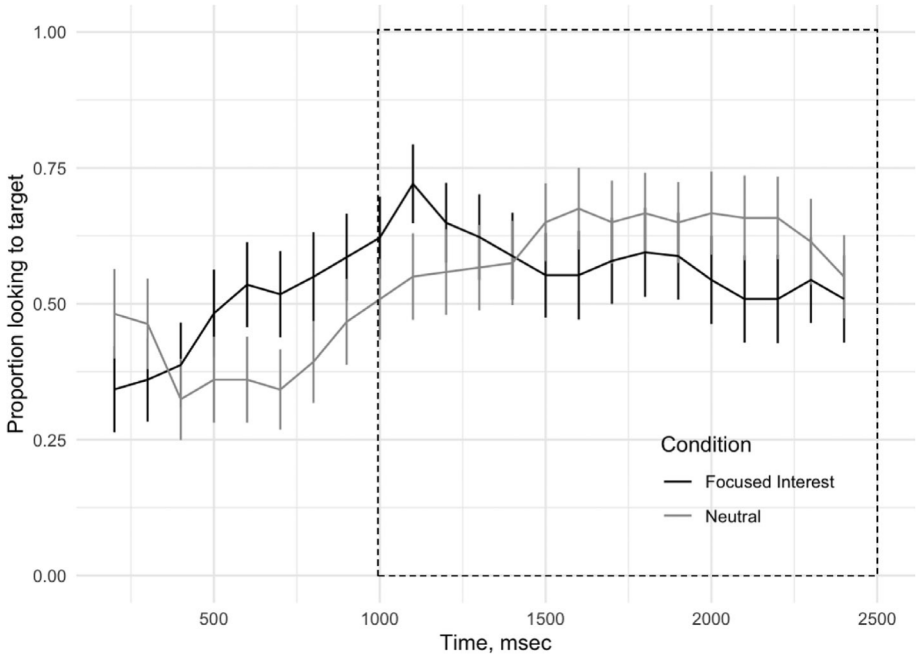


FIGURE 2 Mean proportion of looking to the target during the Test Phase for the autistic group. The *x*-axis depicts time from the beginning of the Response period shown in Figure 1, after children have heard the query (e.g., "Where is doking?"); a second iteration of the query (e.g., "Find doking") began at the onset of this window. Looks to the distractor as well as looks elsewhere are included in the proportion. The analysis window is outlined with a dotted line.

query (50% is a widely-used criterion in developmental studies with autistic and nonautistic children, e.g., Blomquist et al., 2021; Hahn et al., 2015; Horvath et al., 2018; Verdine et al., 2017). Within included trials, individual track loss data points were excluded from analysis. However, data points were included if gaze was directed to neither the target nor distractor (e.g., looking off screen) because our interest was in comparing across conditions rather than comparing to an absolute baseline expectation of looking behavior. This analysis decision differs from some studies using similar paradigms (e.g., Fernald et al., 2001; Golinkoff et al., 1987), which often exclude all looks that are not to either the target or distractor. Notably, research using the related Visual World Paradigm does typically include these data points (see, e.g., Barr, 2008). We think these looks are informative—particularly for autistic children who may have more off-task gaze behavior—and moreover, we included a central fixation before the Response phase, meaning that excluding looks to neither scene would result in missing data as children shifted their gaze from the center to one of the scenes (e.g., Horvath et al., 2018).[5] Thus, each data point was a 1 if gaze was to the target, 0 if to the distractor or elsewhere, and removed if the eyes were not visible (i.e., track loss).

Analyses were performed using *R* Statistical Software (v4.1.2; R Core Team, 2021). Gaze data was formatted using the eyetrackingR package (v0.2.0; Forbes et al., 2021), plots were made using the ggplot2 package (v3.3.5; Wickham, 2016), and statistical tests were done using the lme4 (v1.1–28; Bates et al., 2015), lmerTest (v3.1–3; Kuznetsova et al., 2017), and emmeans (v1.7.4–1; Lenth, 2022) packages. The pre-registered analyses are described first, followed by post-hoc analyses. The main effects of interest (e.g., of condition) are reported in the text; parameter estimates for the pre-registered analyses are available in Table 3, and parameter estimates for post-hoc analyses are reported in the Supplementary Materials.

Pre-registered analyses

Children's gaze is depicted in Figure 2 for the autistic group and Figure 3 for the nonautistic group. The x-axis depicts time from 200 to 2499 ms of the Response phase; the figure thus includes the period before the analysis window begins (minus the 200 ms that autistic or nonautistic children would be expected to require to shift gaze from the central fixation to one of the scenes, e.g., Chawarska et al., 2003). In the analysis window, children looked at either the target or distractor over 92% of the time in both groups and conditions, with the remaining time spent looking to neither scene (e.g., centrally) or coded as track loss. See Table 2.

Per the pre-registered analysis, we asked whether each group showed a difference between conditions in the window from 1 to 2.5 s of the Response phase. For each group, we fit a linear mixed-effects model including a random effect of participant with a random slope for

[5]Following a reviewer suggestion, we repeated the analyses excluding frames on which children were looking to neither the target nor distractor. The patterns were identical except that for the nonautistic children, the interaction between time and condition was not significant ($p = 0.099$). We also repeated all post-hoc analyses with this dependent variable. The results are available on OSF.

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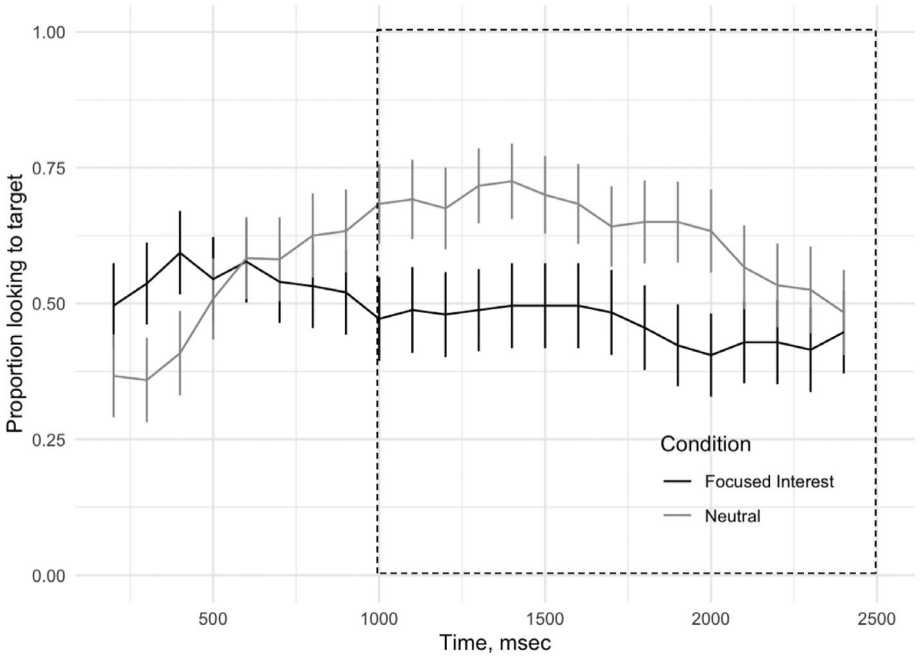


FIGURE 3 Mean proportion of looking to the target during the Test Phase for the nonautistic group. The x-axis depicts time from the beginning of the Response period shown in Figure 1, after children have heard the query (e.g., "Where is doking?"); a second iteration of the query (e.g., "Find doking") began at the onset of this window. Looks to the distractor as well as looks elsewhere are included in the proportion. The analysis window is outlined with a dotted line.

TABLE 2 Participants' mean proportion of looking at the target scene, distractor scene, elsewhere, and track loss during the analysis window of 1–2.5 s of the Response phase by group and condition. Standard deviation is in parentheses. Due to rounding, rows do not add up to 1.

	Target	Distractor	Elsewhere	Track loss
Autistic group				
Focused interest condition	0.58 (0.32)	0.39 (0.30)	0.049 (0.21)	0.037 (0.16)
Neutral condition	0.61 (0.36)	0.33 (0.32)	0.037 (0.20)	0.022 (0.068)
Nonautistic group				
Focused interest condition	0.47 (0.35)	0.50 (0.34)	0.012 (0.19)	0.025 (0.11)
Neutral condition	0.64 (0.32)	0.36 (0.32)	0.0028 (0.045)	0.0050 (0.018)

time[6] and the following variables as fixed effects: time (in seconds, subtracting 1 because the analysis window began at 1 s), condition (deviation coded with the focused interest condition as 0.5 and the neutral condition as −0.5), and the 2-way interaction between time and condition. A significant interaction between time and condition would indicate that children's gaze to the target differed by condition as the analysis window unfolded. See Table 3.

For the autistic group, the pre-registered analysis yielded no significant simple effect of condition ($\beta = 0.23$, $t = 1.39$, $p = 0.16$), indicating no differences between conditions at the beginning of the analysis window, but a significant interaction between time and condition ($\beta = -0.63$, $t = -3.11$, $p = 0.0019$). The interaction reflects a difference between conditions in how children's gaze toward the target unfolded over the course of the analysis window. Post-hoc testing on this interaction using the emtrends function from the emmeans package confirms that the two conditions show significantly different slopes ($t = 3.13$, $p = 0.0020$);[7] gaze to the target in the focused interest condition decreases

TABLE 3 All parameter estimates for the pre-registered analyses.

Parameter	Estimate	SE	*t*-value	*p*-value
Autistic group				
Intercept	0.43	0.22	1.99	0.053
Condition	0.23	0.16	1.39	0.16
Time	−0.057	0.25	−0.22	0.82
Condition × Time	−0.63	0.20	−3.11	0.0019
Nonautistic group				
Intercept	0.46	0.22	2.073	0.045
Condition	−0.98	0.17	−5.66	<0.0001
Time	−0.40	0.26	−1.57	0.12
Condition × Time	0.52	0.21	2.48	0.014

[6]Following a reviewer suggestion, we re-ran these analyses including a random slope for condition. These models did not converge.

[7]Figures depicting the predicted slopes by condition for all models are available on OSF.

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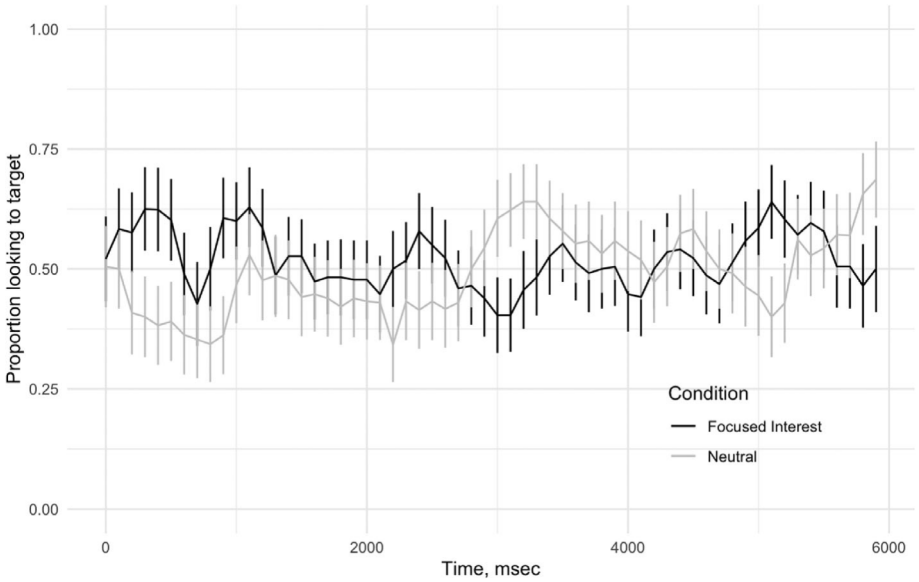


FIGURE 4 Mean proportion of looking to the target during the Baseline Phase for the autistic group. Only looks to the target and distractor are included in the proportion.

over the analysis window, while it increases in the neutral condition. This pattern is likely because children in the focused interest condition had shown an earlier preference for the target, before the pre-selected analysis window began, as evident in Figure 2. A post-hoc (not pre-registered) growth curve analysis (Mirman, 2014) of the portion of the Response phase before the analysis window (from 200 to 999) ms is reported below in the Post-hoc analyses section.

For the nonautistic group, the pre-registered analysis yielded a significant simple effect of condition ($\beta = -0.98$, $t = -5.66$, $p = <0.0001$), and a significant interaction between time and condition ($\beta = 0.52$, $t = 2.48$, $p = 0.014$). The effect of condition indicates that target preference already differed by condition at the beginning of the analysis window (at 1 s), and the interaction reflects a difference between conditions in how gaze toward the target unfolded over the course of the analysis window, as evident in Figure 3. Post-hoc testing on this interaction revealed a significant difference in the slopes ($t = -2.48$, $p = 0.014$); children showed a strong preference for the target with a negative slope in the neutral condition, but in the focused interest condition the slope was relatively flat. Here, too, we included a post-hoc growth curve analysis of the portion of the Response phase before the analysis window, from 200 to 999 ms (see below, in the Post-hoc analyses section).

Post-hoc analyses

We also included three sets of additional post-hoc analyses.

Post-hoc analyses set #1

The first set of post-hoc analyses was aimed at answering the question: Could the children's gaze during the Response phase be driven by the fact that the target scene was the familiar scene, while the distractor scene had not been viewed before? Pilot data (Pelletier & Arunachalam, 2021) suggested that the Baseline phase, during which children saw the two test scenes in silence before being prompted to find the target, would be sufficient to allow children to view and process the novel distractor scene and subsequently have their attention directed by the test query. Nevertheless, it was important to check that this would be the case for the full sample as well. To do so, we examined children's gaze during the Baseline phase of the Test period. Because the distractor scene was novel, we expected that they might prefer it at the beginning of the Baseline phase, but that they would allocate attention to both scenes by the end of this phase. As Figures 4 and 5 show for the autistic and nonautistic group respectively, even an early preference was not clearly evident; we suspect this is because dynamic action scenes may attract children's attention differently because of their movement over and above sheer novelty. Whatever the reason, this outcome suggests that their gaze behavior during the Response phase was unlikely to have been driven by the novelty of the distractor scene.

To further assess gaze during the Baseline phase statistically, we conducted analyses comparing their gaze to the target to "chance" looking over the 6 s Baseline period by removing data points on which children were looking to neither the target nor distractor; this allowed us to test whether children spend more time looking to the target as compared to looking to the distractor. We conducted a series of *t*-tests within each group and condition separately, with the average proportion of target looking across the 6 s serving as the dependent variable. All tests showed that children in both groups were neither significantly above nor below chance at looking to the target during the Baseline phase (autistic focused interest condition: $t(38) = 0.82$, $p = 0.42$; autistic neutral condition: $t(39) = -0.29$, $p = 0.77$; nonautistic focused interest

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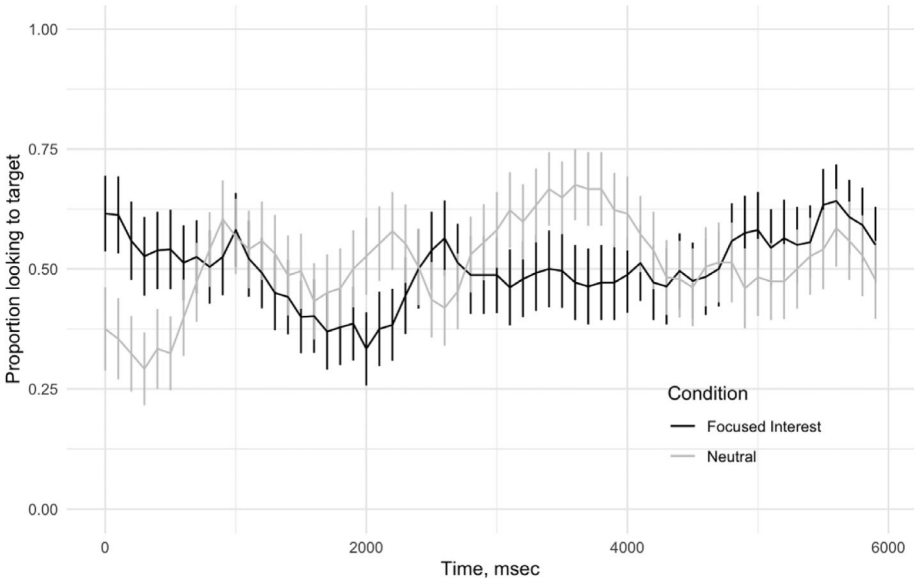


FIGURE 5 Mean proportion of looking to the target during the Baseline Phase for the nonautistic group. Only looks to the target and distractor are included in the proportion.

condition: $t(41) = -0.32$, $p = 0.75$; nonautistic neutral condition: $t(39) = 0.92$, $p = 0.36$). This affirms that children's gaze behavior during the Response phase was unlikely to have been driven by the pre-existing Baseline preferences for target or distractor.

Post-hoc analyses set #2

The second post-hoc analysis was aimed at further understanding children's behavior in the Response phase after being asked to identify the target scene. This approach was described as a possible post-hoc analysis in our preregistration: we included data from both groups and added to the previous model predictors of group (with the autistic group coded as 0.5 and the nonautistic group as −0.5) and its interaction with condition, and vocabulary on the MCDI3 (centered around its mean) (along with condition and its interaction with time as in the previous models). We included a group by condition interaction because the main focus of this analysis was to ascertain whether autistic and nonautistic children differ significantly in how they respond to focused interest vs. neutral trials. We included vocabulary because we might expect that children with larger vocabularies would perform better in a language-learning task, and it was important to include this individual difference variable when combining children from both groups. The random effects structure was as in the previous models. We found no effect of vocabulary ($\beta = 0.0052$, $t = 1.59$, $p = 0.12$) and no effect of group ($\beta = -0.21$, $t = 1.067$, $p = 0.29$), but a significant simple effect of condition ($\beta = -0.39$, $t = -3.21$, $p = 0.0014$) and a significant 2-way interaction between group and condition ($\beta = 0.41$, $t = 3.22$, $p = 0.0013$). The interaction between time and condition was not significant ($\beta = -0.033$, $t = -0.23$, $p = 0.82$). We pursued the 2-way interaction between group and condition with post-hoc Tukey testing using estimated marginal means; the difference between conditions was significant for the nonautistic group ($t = 6.97$, $p < 0.0001$) but not the autistic group ($t = 2.21$, $p = 0.12$); see Supplementary Tables B,C. Thus, while nonautistic children preferred the target significantly more in the neutral condition than the focused interest condition, autistic children showed no such disadvantage in the focused interest condition.

Given these unexpected results, and inspection of Figures 2 and 3, which suggested that nonautistic children may not have learned the novel words in the focused interest condition, we conducted additional analyses to assess whether preference for the target was above chance for each group and condition. As we did for the Baseline period, we removed data points on which children were looking to neither the target nor distractor to test whether children spend more time looking to the target as compared to looking to the distractor, and we conducted a series of *t*-tests within each group and condition separately. We found significant target preferences for the autistic group in both conditions (focused interest condition proportion of target looking = 0.57 ($SD = 0.35$); $t(35) = 2.38$, $p = 0.023$; neutral condition proportion of target looking = 0.60 ($SD = 0.36$): intercept $t(37) = 2.74$, $p = 0.0093$), but in the nonautistic group, target preference was only above chance in the neutral condition (proportion of target looking = 0.63 ($SD = 0.33$); $t(37) = 2.43$, $p = 0.020$), not in the focused interest condition (proportion of target looking = 0.53 ($SD = 0.34$); $t(39) = -0.46$, $p = 0.65$). This suggests that autistic children learned the novel words in both conditions, and nonautistic children only learned in the neutral condition.

Post-hoc analyses set #3

Finally, the third set of post-hoc analyses included a detailed exploration of the timing of children's responses

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during the Response period. This analysis was motivated by visual inspection of the data, which suggested that our pre-selected analysis window of 1 to 2.5 s of the Response Phase was too late, and that children were already showing a preference for the target at the beginning of this time window. Therefore, we pursued growth curve analyses of the period from 200 to 999 ms. For the autistic group, the best-fitting model included second-order (linear and quadratic) orthogonal polynomials, and it included a fixed effect of condition and random effect of participant with a random slope for the linear time term (the model failed to converge with a random slope for the quadratic time term). This model revealed a significant simple effect of condition ($\beta = 0.35$, $t = 2.79$, $p = 0.0054$) and significant interactions between condition and both time terms (interaction with linear term $\beta = 1.22$, $t = 3.56$, $p = 0.0004$; interaction with quadratic time term $\beta = -0.74$, $t = -2.25$, $p = 0.025$), confirming that children's gaze patterns differed between conditions before the analysis window began, as evident in Figure 2. The effect of condition indicates that autistic children looked to the target more in the focused interest condition overall, and that gaze in the focused interest condition increased over time, while it did not in the neutral condition.

For the nonautistic group, the best-fitting model for the period from 200 to 999 ms of the Response Phase included a first-order (linear) orthogonal polynomial, and it included a fixed effect of condition and random effect of participant with a random slope for the linear time term. This model revealed a significant simple effect of condition ($\beta = 0.28$, $t = 2.27$, $p = 0.024$) and a significant interaction between condition and the linear time term ($\beta = -1.021$, $t = -2.92$, $p = 0.0037$). The effect of condition indicates that nonautistic children looked to the target more in the focused interest condition overall, but that gaze in the focused interest condition remained flat over the time window while it increased linearly in the neutral condition.

In summary, taking the pre-registered and post-hoc analyses together, our findings indicate that autistic children showed evidence of increased looking toward the target in both conditions, but that they preferred the target earlier in the focused interest condition than in the neutral condition. Post-hoc comparisons to chance further highlight that the autistic children showed evidence of learning the words in both conditions. For the nonautistic children, our results indicate that they showed a stronger preference for the target in the neutral condition as compared to the focused interest condition, and that the difference between conditions began before and persisted through our pre-selected analysis window. Post-hoc comparisons to chance further highlight that only in the neutral condition was nonautistic children's preference for the target scene sufficiently strong as to indicate learning.

DISCUSSION

Young children—autistic and nonautistic—commonly have focused interests in the preschool and early school age period. Following previous research pointing to the value of these interests for learning, we asked whether children's focused interests could be harnessed for word learning. In contrast to a previous design which explored the teaching of new labels which were intrinsically related to the focused interest (e.g., learning names of vehicles for a child interested in vehicles, Ackermann et al., 2020), we asked whether learning is supported when the focused interest depicted a conceptually unrelated referent. We expected that, across groups, children would perform better when the task invoked their focused interest than when it was depicted by a neutral interest. Results did not align with our hypothesis but in different ways across the autistic and nonautistic groups.

In the autistic group, our pre-registered analysis indicated a difference between conditions in children's attention to the target, with autistic children shifting to the target earlier in the interest condition than in the neutral condition. However, post-hoc analyses indicated that—for the autistic sample—children learned the new word (i.e., performed above chance) in both experimental conditions. The post-hoc analyses are also suggestive of a boost in the focused interest condition as reflected in an earlier preference for the target (even preceding our pre-registered analysis window); future work should pursue this possibility directly. In sum, on the one hand, children on the autism spectrum failed to show the expected learning *advantage* in the focused interest condition; on the other hand, they *did* exhibit—as hypothesized—successful word learning in the focused interest condition and were possibly even faster to demonstrate this learning when their focused interest was present.

In the nonautistic group, the preregistered analysis revealed that the nonautistic group preferred the target more in the neutral condition than in the focused interest condition, and that this preference persisted over the course of the analysis window. Post-hoc analyses revealed a learning disadvantage when the task depicted their focused interest, such that the nonautistic sample learned the new word (i.e., performing above chance) only when the activity relied on a neutral image and not when it invoked their focused interest.

Although this study does not reveal the mechanism by which focused interests affect word learning, the literature offers several possibilities to consider. One set of previous findings points to the importance of visual salience in word learning and has yielded somewhat mixed findings across studies and across diagnostic groups. While Pomper and Saffran (2018) reported that the presence of highly salient familiar objects interrupted novel word learning for nonautistic preschoolers, Venker et al. (2022) reported that highly visually salient novel objects

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supported word learning for nonautistic preschoolers. In contrast, Venker et al. (2022) reported that autistic children failed to learn new words when novel objects were highly visually salient. In locating our findings within these previous reports, it is important to highlight a distinction between these previous studies and the present one: visual salience (as in these prior reports) versus conceptual salience (as in the present study). Here, we aimed to make conditions similar in important visual features (e.g., animacy and size) but different in their cognitive and preferential significance to the child (more on this below). We expect that this contrast might explain the differences observed between the present study and Venker et al. (2022). However, the present report is more similar to the Pomper and Saffran (2018) study, in which salient objects were familiar (not novel, as in Venker et al., 2022), and where the nonautistic children struggled to successfully map new words.

In making further sense of these findings, it is perhaps important to highlight some critical components of the experimental design used in the present study. First, at no point in the training trials was there more than one image on the screen. Second, at no point in the test trials was the neutral interest presented simultaneously as the focused interest. Moreover, the test trials present the *same* image completing different actions; therefore, within trials, the visual salience of the two images is well-matched (though they are completing slightly different movements on the screen). All of these design features reduce the likelihood that "sticky" visual attention (Bryson et al., 2018; Sacrey et al., 2013) is likely to provide a clear explanation for our findings (as in, for instance, Venker et al., 2022). Finally, it is important to note that the action presented was not thematically related to the interest; the character in the image enacted an action that was conceptually unrelated to the interest. In sum, it is important to differentiate visual attention from cognitive processing; that is, to distinguish the demands associated with shifting one's eyes between an image and a different image versus the demands of shifting one's thinking between an image and a different concept. Here, we turn to a second possible explanation for our study findings: focused interests may affect cognitive or attentional processing in different ways for autistic and nonautistic children.

A recent study with autistic and nonautistic adolescents and young adults in a personalized selective attention task found that for nonautistic individuals, items related to their interests yielded automatic top-down priority for attention over other objects; however, autistic individuals did not show this pattern (Parsons et al., 2017). There have been other reports that visual stimuli (especially those with personal salience, similar to the present study) can support higher-level cognitive tasks for nonautistic children, but only if the images are relevant to the mental task; visual images fail to facilitate these cognitive tasks if they are unrelated to the mental activity (Qu & Zelazo, 2007), as they are in the current study. In sum, for nonautistic children in our task, it could be that this automatic, mental prioritization of their interest perhaps diminished their ability to dedicate simultaneous cognitive resources to decipher the (unrelated) meaning of the novel word. This could indicate that nonautistic children's cognitive processing is relatively susceptible to certain aspects of the stimuli, and that this might—under some circumstances—hinder performance by fracturing children's focus.

In contrast, autistic children may have some differences in the way that they process and integrate the various task components demanding their attention (i.e., visual image of focused interest, auditory input presenting the new word). Many previous accounts have characterized attention and cognition in autism as very focused and persistent; some scholars have invoked the idea of "monotropism" to characterize attention in autism (Murray, 1992; Woods & Waltz, 2019). Murray and colleagues (2015) describe monotropism as follows:

> *Our hypothesis is that the difference between autistic and non-autistic is a difference in the strategies employed in the distribution of scarce attention. That is to say, it is the difference between having few interests highly aroused, the monotropic tendency, and having many interests less highly aroused, the polytropic tendency* (p. 140).

The authors discuss how this highly focused attention style can be a detriment when individuals are asked to shift their attention to a task that they see as unmotivating or unrelated to a preferred interest. However, when autistic individuals perceive an activity as connected to their focus of attention, and therefore find that task motivating, this attention style may be advantageous: "If the understanding and the motivation are present, even the least evidently able people with autism may be able to do some things strikingly well" (Murray et al., 2005, p. 144), and that "there may be no problems in integrating information when it is attended to" (p. 141). Finally, the authors suggest that learning (or learning difficulties) may be related to the extent to which instruction has been motivated by personal interests: "We suggest that the uneven skills profile in autism depends on which interests have been fired into monotropic superdrive and which have been left unstimulated by any felt experience" (Murray et al., 2005, p. 143). Our results are broadly consistent with this characterization of attention in autism, particularly in the context of a focused interest.

Although we think that monotropism is an interesting explanation for our results and has support from the literature, it is important to note that another possible explanation for difference across groups in the focused interest condition is simply that the two groups differed in age (in order to allow for matching on vocabulary size).

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Younger children could struggle for the complex processing reason outlined above; in short, younger children have more difficulty in simultaneous cognitive processes. However, we note that the autistic and nonautistic groups overlapped substantially in age. Future researchers might consider whether using multiple comparison groups (i.e., one matched on language level and one matched on age, as well as matching on language measures other than vocabulary size) would enrich our understanding, given that the roles of cognitive processing, attention and focused interests may change over development independently of changes in language ability.

There are some additional important limitations of this work that are important to acknowledge. First, the developmental timing of focused interests is variable across studies, with some indicating that focused interests are established by the preschool years (Alexander et al., 2008; Burrows et al., 2021; DeLoache et al., 2007) and others suggesting an onset closer to age 5 (Nowell et al., 2021). If interests generally emerge closer to age 5, then a slightly older sample than the one we report here might be valuable. Finally, while remote testing in participants' homes offers several advantages, there are challenges associated with measuring eye gaze in response to linguistic stimuli, such as differences in frame rate and differences in the devices that participants used. We did take several steps to mitigate these concerns as described above, and we note that many researchers have replicated findings of in-lab studies using remote procedures (e.g., Luyster et al., under revision; Bacon et al., 2021; Scott et al., 2017).

Finally, in terms of testing word learning, there are a variety of features of our design that must be acknowledged so that future research might consider how performance might vary according to trial features. It is important to highlight that our study employed only one trial per condition (following, e.g., Yuan & Fisher, 2009), and some children did not contribute a useable trial to both conditions (note that our pattern of results did not substantively change when we included only children who contributed data across both conditions). The task also did not require extension of the newly learned word to a new agent—instead, both the target and distractor depicted either the same interest or neutral image as during the training phase; it also only required children to learn one novel label at a time, rather than the more stringent test of learning names for both the target and distractor (Axelsson & Horst, 2013). Additional studies that vary these design features would measure the robustness and generalizability of word learning. Moreover, although our analysis window was based on previous literature, future research could consider the effects of using different time windows (i.e., to avoid gaze shifts that may be less stimulus-driven).

There are a variety of valuable applied implications for the work reported here, the most important of which is that invoking a child's focused interest did not appear to interfere with language learning; to the contrary, invoking a child's focused interest resulted in successful word learning. While there was no apparent learning advantage for invoking children's focused interests, there are associated and important "real world" benefits for doing so. First, for caregivers, providers and clinicians supporting young autistic children, our work aligns with the suggestions of Wood (2021): accepting children's focused interests may be valuable in supporting child participation and communication. Second, it may have collateral benefits for caregivers and instructors, reducing the need for them to offer persistent prompts and direction (Wood, 2021). There are similar ramifications for naturalistic developmental behavioral interventions, in which "clinicians take advantage of a child's *existing interests and preferred activities* as a means to maximize engagement, responsiveness, and skill acquisition" for infants and young children (italics added; Schuck et al., 2021) as well as for clinical programs more broadly (e.g., Harrop et al., 2019). In fact, explicit incorporation of focused interests is central to the design of some intervention protocols, such as "PowerCards" (Gagnon, 2001). Moreover, our work supports a conclusion drawn by another recent word learning study in autistic children highlighting the importance of using stimuli that "appealed to the strengths of children with ASD" (Hartley et al., 2019). We hope that this study, in combination with these other recent advancements, will support the development of motivating, individualized and effective strategies for supporting language development in individuals on the autism spectrum.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to report.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available at https://osf.io/ra4un/.

ETHICS STATEMENT

All study protocols were approved by the Biomedical Research Alliance of New York. Signed informed consent was obtained from caregivers prior to study participation.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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