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BRIEF REPORT

Brief Report: Learning Language Through Overhearing in Children with ASD

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Abstract

We explored whether children with autism spectrum disorder (ASD) learn new nouns from overheard speech. Thirteen children (4–5 years) with ASD participated in an Addressed condition, in which they were directly taught a novel label (e.g., *toma*) for one of three novel objects, and an Overheard condition, in which the objects and label were presented in a conversation between two adults. In both conditions, children were then asked to identify the labeled object (e.g., "find the *toma*"). Children selected the target novel object at rates above chance in the Addressed condition, and of critical importance, they also did so in the Overheard condition. This suggests that, like TD children, children with ASD may learn from language that is not directed to them.

Keywords Autism spectrum disorder · Word learning · Language

Introduction

For individuals with autism spectrum disorder (ASD), the language milestones met during the first (roughly) 5 years of life are especially meaningful for long-term outcomes (e.g., Mawhood et al. 2000; Magiati et al. 2014; Sigman et al. 1999; Venter et al. 1992). As a result, a deeper understanding of early language development in ASD has particular clinical value. When considering how best to support early language development for children with ASD, one central inquiry is, "how do children with ASD learn new words"? Much of the literature on language learning in children has focused on one-on-one caregiver–child interactions involving joint attention. Though joint attention skills are highly variable in this population (Korhonen et al. 2014), children with ASD are often able to use social cues (such as direction of gaze or pointing) in one-on-one interactions to guide language learning (e.g., Akechi et al. 2011; Bottema-Beutel 2016; Luyster and Lord 2009; Parish-Morris et al. 2007), just like their typically-developing (TD) counterparts. To be sure, there is variability in performance according to child characteristics (e.g., age, cognitive level, language level) as well as task demands (e.g., number of labels, salience of social cues).

However, cross-cultural research reveals that TD children do not *require* these one-on-one caregiver–child interactions to learn new words. In some cultures much of children's language input comes in the form of multiparty interactions in which they overhear speech but little is directed to them; these children nevertheless acquire language (e.g., Cristia et al. 2017; Ochs and Schieffelin 1984). Further, laboratory-based research has confirmed that TD children can learn new words via overheard speech (e.g., Akhtar et al. 2001), even as young as 18 months of age (Floor and Akhtar 2006; Gampe et al. 2012). Thus, TD children are skillful at mining their environment for language input, making use of information that is not explicitly provided for their benefit, though overheard speech seems less influential for language outcomes than child-directed speech (Shneidman and Goldin-Meadow 2012; Weisleder and Fernald 2013).

The question of whether children with ASD are able to learn language through overheard speech has both theoretical and practical significance (Akhtar and Gernsbacher 2007). In a fundamental sense, there is value in confirming what language learning mechanisms are present in ASD to define commonalities with and distinctions from TD populations (Arunachalam and Luyster 2016). Moreover, it is important

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to note that much of the language that children are exposed to is overheard (Snow and Ferguson 1977) and not overtly aimed at teaching (Jaswal and Markman 2001); in other words, access to overheard speech drastically increases the quantity of language input a child can make use of. Given the association between quantity of language input and language development for children with (Bang and Nadig 2015; Warren et al. 2010; Sandbank and Yoder 2016) and without ASD (e.g., Hart and Risley 1995), it is worth investigating whether overheard speech offers "learnable" input for children with ASD, thereby potentially affecting the timing and outcomes of early language development. Although this source of input may not be particularly useful for TD children (Shneidman and Goldin-Meadow 2012; Weisleder and Fernald 2013), it may still be useful for children with ASD, who may learn less successfully in joint attention situations than TD children.

As noted above, many previous studies have documented that children with ASD can learn new words in situations where they are directly addressed (e.g., Franken et al. 2010; Hani et al. 2013; Luyster and Lord 2009; Parish-Morris et al. 2007). And although previous literature has found that children with ASD often show reduced attention to social cues (e.g., Dawson et al. 2004; Chita-Tegmark 2016), the present investigation is the first, to our knowledge, to address whether children with ASD are able to use overheard speech to learn new words. In the current study, like other laboratory tasks with TD children (e.g., Akhtar et al. 2001; Floor and Akhtar 2006; Gampe et al. 2012; Shneidman et al. 2009), we focus specifically on word learning, and whether children can acquire an object label in an overhearing situation. To test learning, we focus on novel word comprehension rather than production, because our question of interest is whether children can establish a mapping between the word form and its referent. Our goal is simply to establish proof-of-concept by asking: In a laboratory setting, are children with ASD able to learn new nouns through overhearing? To investigate this, we slightly adapted Akhtar et al.'s (2001) paradigm. Like Akhtar et al., we asked whether children could learn new words in both interactions in which the child is directly addressed—allowing us to replicate prior work—as well as interactions the child merely overhears.

Methods

Participants

Children with an existing diagnosis of ASD under 6 years of age were recruited through a variety of outreach approaches, including established research databases, Facebook/social media, and contact with Boston-area community organizations and service providers. Exclusionary criteria included: primary language other than English, premature birth (before 37 weeks), impaired vision or hearing, and any conditions that may be problematic when using an eye-tracker (such as photosensitive epilepsy), because unrelated parts of the procedure (not reported here) involved eye-tracking. During an introductory screening, we briefly explained the tasks to caregivers and confirmed that their child would tolerate the activities. This recruitment procedure resulted in responses from parents of 17 children with ASD, all ages 4 and 5 years. Finally, for inclusion in the final sample, participants (all of whom reported receiving a diagnosis of ASD during the screening process) were required to meet autism/ASD criteria on a standardized assessment of ASD (the Autism Diagnostic Observation Schedule-2nd edition or ADOS-2), administered as part of the research visits by a research reliable examiner (R.L.). All procedures were completed in a laboratory setting, and children received a small gift for participating.

Of the 17 children who were seen, three were excluded from the final analyses because they did not meet criteria for autism/autism spectrum on the ADOS-2, and one additional participant was excluded for failure to respond on any of the trials. Therefore, the final sample included 13 children with ASD in a within-subject design with two conditions (see Table 1), which is similar to the sample size of 12 per each of two conditions in Akhtar et al. (2001).

Measures

Our primary measure was performance on the word learning tasks (described below). We confirmed ASD diagnosis using the ADOS-2 (Lord et al. 2012), a standardized, semi-structured observational measure that yields algorithm-based classifications indicating autism/autism spectrum or non-spectrum disorder. Comparison scores (i.e., calibrated severity scores) are also derived, which indicate the level of ASD symptom severity on a 10 point rating scale (with higher scores indicating higher symptom levels). Of the 13 participants included in the final sample, three participants received a Module 1 (intended for individuals older than 30 months with very limited expressive language, i.e., single words or two-word phrases at the most), nine participants received a Module 2 (intended for individuals with phrase speech of at least three words) and one participant received a Module 3 (intended for fluent speakers).

Finally, for exploratory analyses addressing how performance on the word learning tasks relates to early communication skills, we included two parent-questionnaire measures. Raw scores from the MacArthur-Bates Communicative Development Inventory II (Fenson et al. 2000) and III (Fenson et al. 2006) were used to measure expressive vocabulary (each form has a possible total of 100). In the current sample, the average score on the MCDI II was 73, which

Table 1 Sample information

Age (years;months)	Gender	ADOS-2 module	ADOS-2 algorithm total	ADOS-2 comparison score	LUI total score	MCDI 2 score	MCDI 3 score
5;1	Male	2	13	6	121	96	76
4;3	Female	2	9	5	107	87	41
4;9	Female	2	21	10	100	50	22
5;9	Male	2	12	6	141	86	68
4;4	Male	3	17	8	141	97	79
4;3	Male	1	22	10	42	47	7
4;10	Male	2	12	6	128	95	87
4;8	Male	1	23	10	44	60	30
5;0	Female	2	14	6	136	80	81
5;0	Female	1	17	6	40	43	23
4;5	Female	2	12	6	114	79	59
4;8	Male	1	16	7	43	49	9
5;4	Male	2	13	6	127	81	71

ADOS-2 Autism Diagnostic Observation Schedule-2nd edition, *LUI* Language Use Inventory, *MCDI* MacArthur Bates Communicative Development Inventory

is roughly equivalent to the 50th percentile for 28-month-old boys (Fenson et al. 2000). Parents also completed the Language Use Inventory (LUI; O'Neill 2007, 2009), and children's LUI total score (based on responses in Part 2 and 3 of the instrument, yields a possible total 161) was used as a composite measure of language and social communication. In the current sample, the average score on the LUI was 99, which is roughly equivalent to the 50th percentile for 28-month-old boys (O'Neill 2009).

Materials

Three familiar objects (spoon, plastic pig and cup) were used in a familiar word comprehension warm-up trial. Six novel objects were used in the word learning task, three in each of two conditions (Addressed, Overheard): a juicer, a noise-maker, a silicone oven mitt, an herb crusher, a wallpaper roller and a melon baller. Two backup novel objects (a rolling magnet and a stretchy toy) were available for use in cases when a parent reported that their child was previously familiar with a novel object. A set of three opaque white buckets (mounted on one wooden plank, called the "hiding apparatus") with lids were used throughout, in order to "hide" and "find" the novel objects in training trials; a small waste-bin with a spinning lid, decorated to look like a penguin, was used in order to increase compliance in comprehension test trials (Luyster and Lord 2009).

Procedures

Ethical approval for all research activities was obtained from the institutional review boards at Emerson College and Boston University. Upon arrival at the laboratory, informed consent was completed with parents/caregivers. Parents were then shown photographs of the novel objects used in the word learning tasks and asked to indicate if their child was familiar with any of the items. If so, that novel object was removed from the task and replaced with a backup item (only one participant required this on one trial). Finally, parents/caregivers were given the parent-report questionnaires to complete; they remained in the testing room during all research activities. The sessions were video-recorded for later verification of word learning coding.

Children first completed the ADOS-2; ADOS-2 scores were based on the live administration. Afterwards, children completed the target word learning tasks, all described below. The experimental procedures were closely modeled on those reported by Akhtar et al. (2001). See Fig. 1. Coding of child responses was done online by the adult assistant and later verified from the videos by another coder. After these word learning tasks, they completed a brief unrelated eye-tracking task (not reported here).

The study followed a within-subject design: each child first completed the Familiar word warm-up comprehension trial, followed by the Addressed (training and test) and Overheard (training and test) conditions, in keeping with previous literature (e.g., Akhtar et al. 2001; Luyster and Lord 2009). Each experimental condition (i.e., Addressed, Overheard) used a different novel word (*modi, toma*) to introduce one of three novel objects. The order in which the two conditions were presented, the assignment of the novel toys to condition, and the assignment of the novel word to object were all counterbalanced across children.

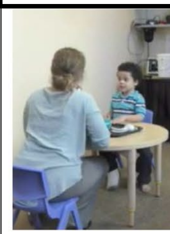
	Training		Test	
Familiar word comprehension warm up (training first, followed by test)		**Target Object:** I'm gonna show you the pig. Let's see the pig. I like this pig. **Distractor Objects:** I'm gonna show you what's in here. Let's see what's in here. I like this one. *(1 round, followed by test)*		**Test 1:** Get the pig and put it in the penguin. **Preference Check:** Get the one you like and put it in the penguin. **Test 2** (not reported): Get the pig and put it in the penguin.
Addressed Condition (training first, followed by test)		**Target Object:** I'm gonna show you the *modi*. Let's see the *modi*. I like this *modi*. **Distractor Objects:** I'm gonna show you what's in here. Let's see what's in here. I like this one. *(2 rounds of training, followed by test)*		**Test 1:** Get the *modi* and put it in the penguin. **Preference Check:** Get the one you like and put it in the penguin. **Test 2** (not reported): Get the *modi* and put it in the penguin.
Overheard Condition (training first, followed by test)		**Target Object:** I'm gonna show you the *toma*. Let's see the *toma*. I like this *toma*. **Distractor Objects:** I'm gonna show you what's in here. Let's see what's in here. I like this one. *(2 rounds of training, followed by test)*		**Test 1:** Get the *toma* and put it in the penguin. **Preference Check:** Get the one you like and put it in the penguin. **Test 2** (not reported): Get the *toma* and put it in the penguin.

Fig. 1 Schematic illustration of study design. The familiar word comprehension warm-up phase (with the word "pig") occurred first for all participants. The order of the Addressed and Overheard conditions, the assignment of novel word to condition, and the assignment of the objects to condition were counterbalanced. For a description of the familiar and novel objects used, see "Materials" section

Familiar Word Comprehension Warm-Up

This trial allowed the examiner to introduce the design of the tasks (using the hiding apparatus, placing objects in the "penguin", etc.) and ensure that the child was able to understand the activity; this trial took about 1 min to complete. The child was seated in a child-sized chair at a small table, with the examiner seated directly across from him/her, and the hiding apparatus was placed on the table between them. The examiner told the child, "I'm going to show you what's in here," and then removed one familiar object from a bucket on the hiding apparatus; this utterance and action was completed for each bucket, one by one. Children were allowed to play with the objects for approximately 30 s. The examiner then placed the three items on a tray and presented the "penguin" and asked, while looking directly at the child's face so as not to provide gaze cues, "Can you put the pig in the penguin?" After the child placed an item in the bin, the item was extracted from the bin and placed back on the tray. The examiner asked the child to identify the one he/she liked and place it in the bin. This served as a preference check to determine which item was the most salient and interesting object in the absence of labeling. Finally, the examiner asked the child again to place the pig in the bin, as a second test of their knowledge. Although children on average succeeded at this second test for the familiar word comprehension warm-up trial, for the two novel word trials, half of the children did not respond at all on this second test or responded by selecting all three objects simultaneously.[1] Therefore, we do not report on performance on the second test question for the procedures described below. Items were placed back on the tray after each selection.

Addressed Condition (Training and Test)

In the Addressed condition, the examiner spoke directly to the participant. Three novel objects were placed in the hiding apparatus, one item in each bucket. Each novel object was used in only one condition, and which bucket the target

[1] One possible explanation for the lack of interpretable response on the second test is that children were confident in their response on the familiar word warm-up, but less so on the novel word trials and that they interpreted our second request as an indicator that their initial response was incorrect. Alternatively, perhaps children were still sufficiently engaged on the second test during the warm-up, but lost interest during the second test on the novel word trials. Akhtar et al. (2001) did not include a second test in their study with TD children.

item was placed in was counterbalanced across participants. Prior to opening each bucket, the examiner said, “I’m going to show you what’s in here. Let’s see what’s in here”; after pulling out and holding up the item for the child to see, the examiner smiled, demonstrated using the object and said, “I like this one!” When introducing the target object, the phrases included a novel label for the object (e.g., “I’m going to show you the toma. Let’s see the toma… I like this toma!”). Each item was replaced before the next item was introduced. After all three items were introduced, they were placed on the table for the child to play with for 30 s; the examiner moved each object into the child’s view to encourage the child to hold each item at least briefly but did not otherwise provide any overt direction or comment (for two children, the experimenter said, “did you see this one?” but otherwise experimenters only smiled and said “mhm” during this time, even if the child tried to initiate conversation). The items were then placed back in the bucket and the entire sequence was repeated, for a total of two rounds in the training phase, which took roughly 2 min in total.

The comprehension test immediately followed the two training rounds. The items were placed on a tray, next to the “penguin”. The child was asked to “Get the toma and put it in the penguin.” After their selection, the item was replaced and the child was asked to “Get the one you like and put it in the penguin.” This served as a preference check. The item was replaced and, finally, they were again asked to “Get the toma and put it in the penguin”; as noted above, performance on this second test is not reported.

Overheard Condition (Training and Test)

The training phase proceeded in a similar fashion as described for Addressed, with a different set of novel items and a different label. This time, rather than speaking to the child, the examiner addressed an adult assistant, both of whom were seated three feet in front of the child, who remained seated at the table. The hiding apparatus was placed in between the examiner and the adult assistant. The child was not explicitly told to watch the interaction, nor were they given any objects or materials; instead, they were told, “I’m going to play over there with my friend, and then I’ll be right back.” All objects were removed from the table, although children were not prevented from moving around the room and could have gotten up to retrieve other toys, sit with their parent, etc., if they wished. (Due to experimenter error, the experimenter did ask one child to sit, and one of the children’s parents asked them to sit.) The child was offered the opportunity to play with the set of items at the end of each training round as in the Addressed condition. The training phase took approximately 2 min to complete, and comprehension tests proceeded as described above for the Addressed condition.

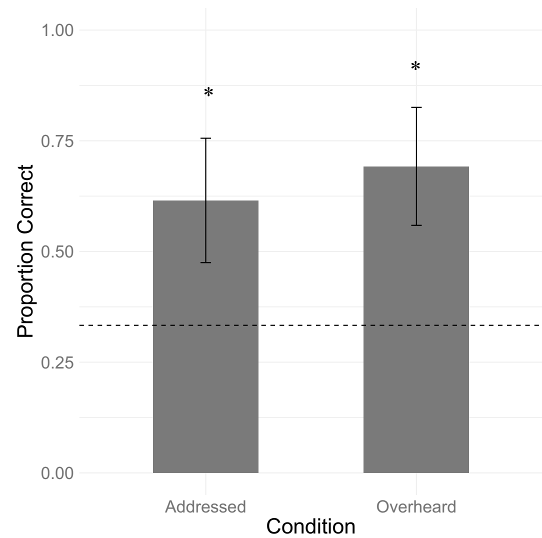


Fig. 2 Proportion correct responses by condition. Chance performance is depicted by the dotted line. Asterisks indicate greater than chance performance, $p < .05$. Error bars indicate standard error

Results

On the familiar word comprehension warm-up, all children but one performed correctly. The pattern of findings is the same whether this child’s data is included or excluded; it is included below. The dependent variable was based on children’s response to the first test trial in the Addressed condition and the first test trial in the Overheard condition (the second test trial was excluded as discussed above). Specifically, we tested whether children selected the novel, target (labeled) object out of the array of three objects. Two children responded in one condition test, but failed to select any toys at all during the test phase on the other condition: one child failed to respond in the Overheard condition and the other failed to respond in the Addressed condition. To be conservative, we have included those two trials in the analysis below as incorrect responses, although the patterns are identical (with even larger effect sizes) if we instead exclude them from analysis.

Overall, children succeeded in the task; they chose the correct novel object 62% of the time in the Addressed condition and 69% of the time in the Overheard condition. Chance performance is 33% given that three novel objects were presented. See Fig. 2. Six of the 13 children succeeded in both conditions, three succeeded in Overheard but not Addressed, two succeeded in Addressed but not Overheard, and two failed both conditions.

To assess performance statistically, we used two approaches. Our first and primary measure was intended to replicate prior evidence that children with ASD can learn in Addressed conditions, and determine if they can also learn in Overheard conditions. We used a binomial test on the data from each condition to determine whether performance was above chance. In the Addressed condition, a binomial test indicated that the observed success rate of 62% was significantly higher than the chance level of 33%, one-tailed $p < .04$. In the Overheard condition, too, the success rate was significantly higher than chance, one-tailed $p < .01$. If the tests are re-run excluding trials on which children picked the same item for preference and test, the results are still significant for Overheard ($p = .04$), but not for Addressed ($p = .14$). Note that Akhtar et al. (2001) found a similar rate of selection of the same object for preference and test trials (17%, to our 23%.) We also calculated the "relative risk" (i.e., likelihood) of success against chance for both conditions as a rough measure of effect size. Values greater than one indicate a higher relative risk (i.e., higher likelihood of success relative to chance); values less than one indicate a lower relative risk (i.e., lower likelihood of success relative to chance); both were > 1 (Addressed RR = 1.85; Overheard RR = 2.08), indicating that children selected the target item at rates above chance across both conditions. Thus, we replicated the expected finding for the Addressed condition, and further found that children with ASD can also learn from Overheard speech. These findings were not driven by the order in which the trials were administered (Addressed first or Overheard first); in *both* conditions, children performed better on the first trial in which they participated (Addressed first: Addressed 86% correct, Overheard 57%; Overheard first: Addressed 33% correct, Overheard 83%).

Second, we conducted exploratory analyses on relationships between task performance and language and communication ability as measured by our small assessment battery. The instruments we administered were selected to align with the literature in TD children. Given the minimal variability in the word learning task, it is perhaps not well suited for studying individual differences (Hedge et al. 2017). Nevertheless, our results suggest that performance in the Addressed condition, but *not* Overheard condition, correlates with measures of language and social communication skill (i.e., LUI, MCDI-2 and -3; see Table 2), but in neither condition does it correlate with autism severity. Individual tests comparing the correlations with Addressed versus Overheard conditions to each other (Steiger 1980) confirmed that the correlations were significantly different for LUI ($z = 2.68$, $p = .007$) and MCDI 3 ($z = 2.49$, $p = .01$), but not for MCDI-2 ($z = 1.34$, $p = .17$)

Finally, because attention to the experimenters in the Overheard condition could be related to performance (Akhtar 2005; Shneidman et al. 2009), we also coded children's behavior from the videos of the sessions. Five of the children got up from their seats during the experimenters' interactions, but all but two of the children (one who got up, and one who remained seated but put her head down) appeared to be watching the experimenters' interaction for at least one presentation of the novel word; only one of those two children failed in the Overheard condition.

Table 2 Correlations by experimental condition

	Addressed		Overheard	
	r	*p*	*r*	*p*
LUI total	.87*	< .001	.18	.55
MCDI 2	.64*	.018	.19	.53
MCDI 3	.79*	.0011	.05	.86
ADOS-2 comparison score	− .24	.43	.03	.92

LUI Language Use Inventory, *MCDI* MacArthur Bates Communicative Development Inventory, *ADOS-2* Autism Diagnostic Observation Schedule-2nd edition

*$p < .05$

Discussion

We set out to establish proof-of-concept by asking: In a laboratory setting, are children with ASD able to learn new nouns through overhearing? We adapted a laboratory-based paradigm established for TD children by Akhtar et al. (2001), which has shown successful word learning in overhearing contexts in children as young as 18 months. Children were exposed to a novel word labeling a novel object in one of two conditions: in one, the child was directly addressed by the experimenter, who ostensively labeled the object; in the other, the experimenter labeled the object for another adult while the child was in the room. Our results converge with prior research with TD children (e.g., Akhtar et al. 2001; Akhtar 2005; Floor and Akhtar 2006): children with ASD succeeded in both Addressed and Overheard contexts, indicating that they can learn nouns from overheard speech. Furthermore, our observed effect sizes (i.e., "relative risk", or likelihood of selecting the target object relative to chance: Addressed RR = 1.85; Overheard RR = 2.08) are similar to those derived from Akhtar et al. (2001) with TD children aged 2;6 (Addressed RR = 3.33; Overheard RR = 3.33) and TD children aged 2;1 (Addressed RR = 0.75; Overheard RR = 2.25); and Gampe et al. (2012) with TD children aged 1;6 (Addressed RR = 1.54; Overheard RR = 1.91).

Further preliminary analyses indicated that task performance was not related to language and communication measures for the Overheard condition, though it was for the Addressed condition. Thus, we find no evidence that overhearing ability in laboratory-based tasks is associated with concurrent social and communication skills. Importantly, however, we do not know if the same is true for TD children, as traditional lab-based studies of overhearing have generally not included analyses of relationships to concurrent language ability (Akhtar et al. 2001; Akhtar 2005; Floor and Akhtar 2006; Shneidman et al. 2009; Gampe et al. 2012). Interestingly, performance in the Addressed condition was particularly associated with child scores on the LUI and MCDI 3. One possible interpretation of these contrasting results is that the Addressed training task may more closely approximate a "real-world" activity in which a parent introduces a new object label, while the Overheard task is much more tightly controlled than a naturalistic setting. Indeed, little is known about how overhearing skills manifest in naturalistic settings, which is arguably more relevant for concurrent ability than these laboratory-based activities. But even if learning from overheard speech does not play an important role in language learning in daily life for children with ASD, it could still be useful in treatment settings. After all, interventions involve some degree of control over the child's environment or of the interactions the child is involved in, just as laboratory situations do. Because learning from overheard speech appears to be an intact mechanism, it might be a strategy that clinicians can use to promote language development for some children with ASD (Pepperberg and Sherman 2000, 2002), particularly those who are overwhelmed by social stimuli and may struggle to learn in one-on-one interactions (e.g., Pierce et al. 1997). It may also be useful for learning some kinds of words in particular; several studies have shown that acquisition of personal pronouns benefits from access to overheard speech in TD children (e.g., Oshima-Takane 1988; Oshima-Takane et al. 1996). For children with ASD, who struggle with pronoun acquisition (but see Naigles et al. 2016 for evidence from 15 children that this difficulty may be relatively small) overheard speech may be especially useful (Arunachalam and Luyster under revision; Oshima-Takane and Benaroya 1989).

In an important follow-up study to her original work on TD children's ability to learn novel words from overheard speech in the laboratory, Akhtar (2005) found that this ability was robust even when children were given distracting toys to play with while the novel word was being introduced. This required children to shift their attention from their own toy to attend to the experimenters' interaction. It remains to be seen whether children with ASD are also able to do this. However, in another classic paradigm, in which children must assign a novel label to an object in the experimenter's locus of gaze rather than their own (Baldwin 1993a, b), some children with ASD can succeed, particularly those with some early social communication skills (Luyster and Lord 2009). The children in the current sample showed similar foundational skills: all children had some expressive language and all of those tested on joint attention on the ADOS-2 successfully responded to a joint attention bid. When directly addressed, at least, at least some children with ASD can learn nouns even with distractions; it will be essential for future research to expand these findings to overhearing situations.

Limitations

The methods that we used focused on nouns and employed a strictly controlled laboratory-based task. Future research should explore the ability of children with ASD to learn other word types via overhearing (e.g., verbs and pronouns, see Arunachalam and Luyster under revision, for discussion), as has been the case in the TD literature (Akhtar et al. 2001; Oshima-Takane 1988), and should also probe the "real-world" applicability of this apparent skill—that is, are children able to learn through overhearing in daily settings? We also note that our sample size is small. This limits the generalizability of our findings and may reduce the likelihood that they can be reproduced (Button et al. 2013). It also introduces the risk that the above-chance performance may not reflect a true effect (Button et al. 2013) and limits our ability to interpret the null effect of condition—that is, our finding that children did not perform better in overheard situations than addressed situations, or vice versa. We also lacked detailed measures of some relevant language abilities, such as receptive vocabulary size, which is extremely difficult to measure in this young population (e.g., Charman et al. 2003; Luyster et al. 2008). This study therefore serves as a proof-of-concept; we hope that future work with larger samples will establish in more detail relationships between children's performance in this task and other aspects of their profiles with a fuller test battery, in both TD and ASD samples.

Another important note about the sample tested in the present study is that it included children who were relatively skillful (all children had some spoken language and basic joint attention skills), many of whom were beyond the single-word level of expressive speech. Our results showed strong abilities to learn from overheard speech, comparable to learning from addressed speech, but it could still be that in a more heterogeneous sample we would find greater variability in performance, as well as evidence that access to overheard speech is predictive of language outcomes. Future research on learning in overhearing contexts should incorporate a heterogeneous sample to explore generalizability of our findings, and should also include a range of language and social communication measures to look for relationships between performance and linguistic skill. Finally, it will be important for upcoming studies to enroll a control group of TD children, rather than—as we have—relying on previous estimates in the literature to serve as a comparison point.

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Author Contributions RJL and SA contributed equally to this work.

Compliance with Ethical Standards

Conflict of interest Rhiannon Luyster is an author on the ADOS-2 and receives royalties from sales. S. Arunachalam declares that she has no conflict of interest.

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