Can children with Autism Spectrum Disorders learn new vocabulary from linguistic context?

Key Words: autism spectrum disorder, language impairment, vocabulary instruction, word learning, context

Abstract

This study investigated whether children with Autism Spectrum Disorders (ASD) can learn vocabulary from linguistic context. Thirty-five children with ASD (18 with age-appropriate structural language; 17 with language impairment [ALI]) and 29 typically developing peers were taught 20 Science words. Half were presented in linguistic context from which meaning could be inferred, whilst half were accompanied by an explicit definition. Children with ASD were able to learn from context. Condition did not influence phonological learning, but receptive semantic knowledge was greatest in the context condition, and expressive semantic knowledge greatest in the definitional condition. The ALI group learnt less than their peers. This suggests that at least some vocabulary should be taught explicitly, and children with ALI may need additional tuition.

Introduction

Vocabulary knowledge is essential for effective communication and social development, but it is also a strong predictor of academic success and employment outcomes (Feinstein & Duckworth, 2006; Morgan, Farkas, Hillemeier, Hammer, & Maczuga, 2015). It is therefore important that we understand the optimal ways to teach, and for children to learn, new vocabulary. This is especially pertinent for children with communication disorders, such as Autism Spectrum Disorders (ASD). Over 65,000 children with ASD are currently being educated in mainstream schools in England (Department for Education, 2015), yet children with ASD may not benefit from the same teaching methods as their typically developing (TD) peers. While TD children are efficient at learning new words implicitly from context (Swanborn & de Glopper, 1999), this may not be the case for children with ASD, many of whom have difficulties making inferences (Lucas & Norbury, 2015; Norbury & Bishop, 2002). The current study therefore examined the extent to which school-aged children with ASD are able to learn phonological and semantic aspects of new words when meaning must be inferred from the surrounding linguistic context, relative to when the word is accompanied by an explicit definition. The study also investigated whether there were any quantitative or qualitative differences in the information children with ASD and their TD peers learnt about the words, and whether these differences were influenced by language phenotype within ASD.

Oral vocabulary learning in typical development

Research investigating vocabulary acquisition in middle childhood tends to focus on the semantic knowledge attained from presentation of either definitional or contextual information, rather than directly comparing the two. For example, Henderson, Weighall, and Gaskell (2013) taught TD children Science words by providing a picture of the referent with the phonological form of the word and a brief spoken definition. At pre-test only 2% of the words were familiar to the children, but following semantic training participants attained an average of 74% accuracy on a word-picture matching task and 25% accuracy on a definition production task. These rates of learning are higher than word learning from longer, naturalistic context. Swanborn and de Glopper (1999) conducted a meta-analysis of 20 incidental word-learning studies, and found that on average, children learn 15% of the novel words encountered in natural contexts.

One of the few studies which has directly compared both modalities was conducted by Nash and Donaldson (2005). They reported that both younger (mean age = 4;5) and slightly older TD children (mean age = 7;0) acquired greater in-depth expressive and receptive semantic knowledge (as indexed by definition production and meaning recognition tasks) when words were taught with an explicit spoken definition rather than embedded in an oral narrative from which the meaning could be inferred. However, phonological knowledge (as indexed by picture naming and spoken word recognition tasks) and low-level receptive semantic knowledge attainment (as indexed by a word-picture matching task) was similar in both conditions. Whilst this may indicate that the optimal mode of instruction is dependent upon the type of knowledge to be learned, it is important to consider the equivalency of learning opportunity across the two conditions. In the definition condition the items were presented individually and therefore attention was directly drawn to each word and word meaning. In contrast, in the context condition all of the words were presented at the same time in one narrative. Furthermore, while the context condition involved passive listening, the definition task involved active learning through the introduction of questions related to the items. It is therefore difficult to determine whether differences in knowledge acquisition were due to the mode of presentation per se or due to additional differences in exposure and participation between the two conditions.

Vocabulary learning in ASD

Autism spectrum disorder (ASD) is characterised by persistent impairments in social communication and interaction, as well as restricted or repetitive patterns of behaviour, interests or activities (American Psychological Association, 2013). Research with school-aged children has focused on explicit teaching of new vocabulary, examining questions such as the extent to which orthography can facilitate vocabulary acquisition (Lucas & Norbury, 2014; Ricketts, Dockrell, Patel, Charman, & Lindsay, 2015), ability to learn from social cues such as eye gaze (McGregor, Rost, Arenas, Farris-Trimble, & Stiles, 2013; Norbury, Griffiths, & Nation, 2010) and integration of new words into the lexicon (Henderson, Powell, Gaskell, & Norbury, 2014). However, all have included measures of both phonological and semantic learning.

These studies indicate that phonological processing and word production during the learning phase are similar for children with ASD and their TD peers (Henderson et al., 2014; Ricketts et al., 2015). However, at post-test children with ASD are more successful than their TD peers at mapping phonological forms to novel referents (Lucas & Norbury, 2014; Norbury et al., 2010). Similarly, initial semantic learning (as indexed through word-picture matching task accuracy) is similar for children with ASD and their TD peers (Lucas & Norbury, 2014; McGregor et al., 2013; Norbury et al., 2010). However, on a more nuanced measure, a definition production task, Norbury et al. (2010) found that relative to their TD peers children with ASD recalled fewer semantic details of novel immediately after learning, and the discrepancy was more pronounced four weeks later.

Crucially, the participants in these studies were carefully matched to their TD peers on potentially influencing factors such as chronological age and non-verbal ability. However, the language skills of the ASD participants were either age-appropriate (Henderson et al., 2014; Lucas & Norbury, 2014; Norbury et al., 2010) or heterogeneous (McGregor et al., 2013; Ricketts et al., 2015). This raises the question of whether these results are applicable to all children with ASD, or whether vocabulary learning varies for children with different language phenotypes. Within ASD there are at least two core language phenotypes (Kjelgaard & Tager-Flusberg, 2001) and whilst some children with ASD have age-appropriate structural language skills (Autism Language Normal; ALN) over 50% have concomitant language impairment (Autism Language Impaired; ALI; Kjelgaard & Tager-Flusberg, 2001; Loucas et al., 2008). Notably, phonological skills and vocabulary knowledge align with grammatical language skills, such that children with ALI perform more poorly on such measures than their ALN (and TD) peers (Lindgren, Folstein, Tomblin, & Tager-Flusberg, 2009). It is therefore feasible that acquisition of phonological and semantic details may be especially fragile for children with ALI. Indeed, non-autistic children with language impairment find learning new vocabulary more challenging than their TD peers (cf. Kan & Windsor, 2010).

Notably, studies examining vocabulary learning for school-aged children with ASD have focussed on learning from explicit instruction. However, there are too many words children need to acquire in order for them all to be taught this way. TD children can learn words from context, but the proficiency of children with ASD at doing this is unknown. In order to derive semantic knowledge of words from the surrounding linguistic context inferencing is required. Inferencing is a complex skill that requires an individual to go beyond what is explicitly stated and integrate information with prior linguistic and cognitive knowledge. It is a higher-order language skill that many children (Lucas & Norbury, 2015; Norbury & Bishop, 2002), adolescents (Norbury & Nation, 2011; Saldaña & Frith, 2007), and adults (Jolliffe & Baron-Cohen, 1999) with ASD find challenging, even when structural language skills are intact. This suggests that inferring the meaning of new words from the surrounding context may be problematic for children with ASD, and thus they may learn vocabulary better when it is presented accompanied by an explicit definition.

However, inferencing skill closely aligns with language skill for individuals with ASD (Jolliffe & Baron-Cohen, 1999; Lucas & Norbury, 2015), and non-autistic children with language impairment also find inferencing more challenging than their TD peers (Adams, Clarke, & Haynes, 2009; Bishop & Adams, 1992; Crais & Chapman, 1987; Dodwell & Bavin, 2008; Ellis Weismer, 1985; Karasinski & Weismer, 2010). It is therefore plausible that learning from context may be especially problematic for individuals with ASD with concomitant language impairment.

Consistently, Cain, Oakhill, and Lemmon (2004) found that non-autistic children with weaker language skills were poorer at inferring the meaning of novel words embedded in stories than children with age-appropriate language skill. Yet when novel words were presented with explicit definitions, there were no group differences in recall of semantic information. However, whilst the definitional information was provided verbally to the children, they were required to read the stories themselves, thereby increasing the task demands and reducing the equivalency of the conditions. Nash and Donaldson (2005) similarly found that non-autistic children with language impairment acquired greater deeper-level receptive and expressive vocabulary knowledge when words are taught accompanied by an explicit definition rather than presented in a story. However, as previously discussed, the conditions in this study were also not equivalent, therefore further investigation is required.

The current study

The current study extends our knowledge of vocabulary acquisition for children with ASD in two keys ways. First, rather than solely focusing on learning from explicit instruction, we also investigate learning from context. Second, we consider the influence of language phenotype by comparing children with ALN to those with ALI. Notably, the stimuli utilised in this experiment were real, low frequency, Science words from the UK National Curriculum, rather than non-words. It is questionable whether participants generally, and children with developmental disorders in particular, treat non-words in a similar fashion to words which have some relevant meaning (Potts, John, & Kirson, 1989). Thus using real words is especially important for establishing evidence based strategies for teaching and learning in ASD (cf. Henderson et al., 2013).

We predicted that the phonological learning of children with ALN would be similar or enhanced compared to that of their TD peers, and both these groups would outperform children with ALI. We did not anticipate a main effect of training condition (i.e. verbal definition versus verbal context) for phonological learning for any group. However, for semantic learning, we expected that children with ASD would acquire greater semantic knowledge from the definition than context training condition, and that this would be most evident for children with ALI (given that children with language impairments find inferencing especially challenging). Additionally, we anticipated that children with ALI would provide more inaccurate semantic information and/or more indeterminate responses in the context condition than definition condition, perhaps as a result of inaccurate inferences. We expected TD children to acquire greater semantic knowledge than both their ALN and ALI peers, and did not anticipate an effect of condition for the TD group.

Method

Participants

Sixty four children aged 8-13 years were recruited from schools in southeast England. All children with ASD (ALN *n* = 18, 14 male, ALI *n* = 17, 13 male) held an existing diagnosis from a multi-disciplinary clinical team external to the research group based on DSM-IV/ICD-10 criteria. They were also currently in receipt of a statement of special educational need, and attended a specialist school or unit serving children with ASD. Autistic symptomatology was quantified using the Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003). This 40-item dichotic answer questionnaire comprises parental report of both current and lifetime behaviours that are indicative of ASD. For children aged 8+, scores >15 are indicative of ASD. Twenty-one parents of children with ASD completed the SCQ and scores ranged from 6-32. Two children with ALN received scores below the indicative ASD range (scores of 6 and 12), but given their clinical diagnosis they were still included in the study. Children with ALI were also receiving additional support for structural language difficulties. They also attained a scaled score <7 on the Clinical Evaluation of Language Fundamentals (CELF-4UK; Semel, Wiig & Secord, 2003) Recalling Sentences subtest, which is considered to be a robust clinical marker of language impairment (Botting & Conti-Ramsden, 2003; Conti-Ramsden, Botting, & Faragher, 2001; Riches, Loucas, Charman, Simonoff, & Baird, 2010). TD children (*n* = 29, 16 male) were recruited from local schools and did not have any reported special educational needs, history of ASD, language delay or literacy difficulties. Twelve parents returned the SCQ, and scores ranged from 0-8, i.e. within the typical range. The protocol was approved by the Research Ethics Committee at XXX. Informed, written consent was obtained from all parents and verbal assent was obtained from all children.

Non-verbal cognitive ability (NVIQ) was assessed using the Matrix Reasoning sub-test of the Wechsler Abbreviated Scales of Intelligence (WASI; Weschler, 1999). Vocabulary knowledge was measured using the Receptive One-Word Picture Vocabulary Test (Gardner, 1990) a spoken word to picture matching task, with the exception of 15 TD children who completed the WASI Vocabulary subtest instead (mean = 51.69, SD = 8.30). All three groups were matched at a group level for chronological age. In addition the TD and ALN groups were matched at a group level on all cognitive and language measures, whereas the ALI group had significantly lower scores. Nevertheless, the ALN and ALI groups were matched on autistic symptomatology, as indexed by SCQ scores (Rutter et al., 2003), whilst the TD children had significantly lower SCQ scores (see Table 1).

INSERT TABLE 1 HERE

Materials

The stimuli were 20 low-frequency words associated with the UK secondary school (ages 11-16) Science curriculum. We consider words more accessible and motivating for children with ASD and their TD peers than non-words, and there is a lack of consensus on whether children with ASD treat non-words similarly to concrete words with relevant meaning (Potts et al., 1989). The stimuli were a subset of words included in Henderson et al. (2013) and the words were related to either animals (e.g. mastodon), plants (e.g. lantana) or neither animals nor plants (e.g. catalyst). Stimuli properties e.g. age of acquisition were acquired by Henderson et al. from 18 educational professionals (teachers, teaching assistants) and researchers who work with children (see Table 2 for stimuli properties and the Appendix for item specifics). The images were colour photographs used by Henderson et al. (2013), which were obtained from www.clipart.com and www.fotosearch.com/clip-art, as children are better able to generalise word meanings from picture books if these contain realistic colour photographs or drawings than simple line drawings (e.g., Simcock & DeLoache, 2006, 2008; Tare, Chiong, Ganea, & DeLoache, 2010).

INSERT TABLE 2 HERE

Procedure

The test battery was administered in two 40 minute sessions over two different days. Participants were tested in a quiet room within their school. The experiment was run on a laptop computer and was programmed using E-Prime software (Psychology Software Tools, Pittsburgh, PA). The session was divided into ‘learning’ and ‘testing’ phases. Prior to the learning phase, each word was heard once and children were asked whether it was a word they knew. Any YES responses were probed further (i.e. requesting that the child provided a definition ‘what is an X’). This procedure assessed whether the stimuli were unknown and familiarised the children with the words prior to learning (cf. Lucas & Norbury, 2014; Ricketts et al., 2009).

Initial familiarity with the items was low. Thirty-six percent of children were not able to provide an accurate meaning of any of the words, whilst 43.75% were familiar with only one or two of the items in the stimuli sets. It was initially anticipated that pre-test familiarity would be accounted for by recoding task raw scores into percentage accuracy for unknown words. However, examination of the individual data indicated that participants did not necessarily attain maximum scores at post-test on all of the items they accurately provided a definition for at pre-test. For example, 13 children (8 TD, 2 ALN, 3ALI) were unable to accurately name the items represented pictorial in the picture naming task that they had accurately provided oral definitions of at pre-test, suggesting only partial-existing knowledge. There were no significant group differences (TD vs ALN vs ALI) in the percentage of words that were familiar at pre-test, $F(2, 61) = .37$, $p = .693$, $\eta_p^2 = .012$, therefore, total raw scores were used in the analysis.

During the first session, 10 of the items were taught either in the definition or the context condition and learning was tested immediately afterwards. The remaining 10 were taught in the alternative condition the following day, and learning for these words was also tested immediately. The two stimuli sets were counterbalanced across conditions and the order of conditions was counterbalanced across participants. During the learning phase (see Figure 1), the child viewed the picture referent for 500ms while presented with the spoken form of the word. The child repeated the word aloud and accuracy was recorded; repetition accuracy was high for all three groups (TD: M = 9.67, SD = .60; ALN: M = 9.33, SD = .85; ALI: M = 9.04, SD = .47). Then the child was presented with an audio version of either the definition or context, without the picture present. The contextual sentences contained on average more words than the definitional sentences, as is the case with previous studies (e.g. Nash & Donaldson, 2005; Nash & Snowling, 2006). However, crucially, both conditions contained similar key details and provided both categorical and attributional information. For example, for the item ‘hippocampus’ the definition provided was: “The hippocampus is a part of the brain that helps you remember” and the contextual information was “Doctors can sometimes see damage to the hippocampus when they look at scans of the brain. People with this kind of brain damage often have trouble remembering things.”

Following the first presentation of all stimuli, each item was presented again in the same manner, with the order randomised. In the final part of the learning phase, the child again viewed a picture for 500ms which was accompanied by the spoken word label. The child then indicated whether the word was associated with animals, plants or neither through a key press and received visual feedback on response accuracy. This semantic categorisation task reinforced attention on the semantic properties of the stimuli and helped maintain interest during the learning phase. Accuracy on this semantic decision task was high for all three groups in the definition condition (Mean TD = 8.88, ALN = 8.94, ALI = 8.44), with no group differences, F(2,

60) = 1.07, *p* = .350. Accuracy was also high in the context condition (Mean TD = 8.76, ALN = 9.13, ALI =7.94), although subtle group differences emerged, $F(2, 58) = 4.83$, $p = .012$, $\eta^2 = .14$. There was a trend for the ALI group to have lower accuracy than their ALN peers ($p = .062$).

After the learning phase, one of the standardised assessments was administered for approximately 7 minutes before the test phase commenced. Another standardised task was completed at the end the test phase. Learning was assessed via three post-tests (see Figure 1). First, children were presented with a picture and asked to name it to assess phonological learning. Presentation order was randomised and total accuracy was recorded. An unprompted correct response was awarded 2 points. If a child could not accurately respond, then they were provided with the first phoneme of the word, and a subsequent correct response received 1 point. Second, a word-picture matching task was administered to measure low-level receptive semantic knowledge of the newly learned words. The child heard a spoken word accompanied by four images: the target stimuli and three distractor items from the stimulus set. Children identified the target stimuli picture by pressing the appropriate keyboard key. Presentation order was randomised and accuracy was recorded.

More detailed expressive semantic knowledge was then measured via a semantic retrieval (definition production) task. A pictorial referent was presented accompanied by the spoken form of the word and the child was instructed to “tell me what X means?”. Answers were scored on-line, but also audio recorded then transcribed so scoring could be confirmed off-line. Responses were first coded for overall semantic retrieval accuracy (0 for no recollection, 1 for partial recollection, and 2 for complete recollection), following the procedure of Cain et al. (2004) and Nash and Snowling (2006). Previous word learning studies have emphasized the importance of different types of information for complete semantic knowledge, for example categorical, physical and functional (e.g. Dockrell, Messer, George, & Ralli, 2003; McGregor, Newman, Reilly, & Capone, 2002). Therefore, scores for complete recollection were only given when responses included categorical information (e.g. for hippocampus, ‘it’s part of the brain’ and for ratite, ‘it’s a bird’) along with attributional information specific to that word (e.g. ‘it helps you remember things’ or ‘it cannot fly’). Each item was scored independently by both the first and second author blind to the child’s diagnostic status. The inter-rater reliability was 97.86% for the definition condition and 96.43% for the context condition. All items with discrepancies only differed by 1 point and the final mark awarded was derived via discussion.

In addition to understanding the amount of accurate information learnt from each condition, we were also interested in whether the children provided any inaccurate information about the stimuli (semantic retrieval errors). Information was classed as inaccurate if it was actually incorrect, rather than if it was just too vague. For example, child 104 described a pantograph as “a little pen”, rather than as a machine that stores electricity. This type of inaccuracy was coded as a semantic error, but the number of indeterminate errors (e.g. don’t know responses) were also examined, following the distinction between these two types of inaccuracies made by McGregor et al. (2002).

INSERT FIGURE 1 HERE

Results

Phonological knowledge: Picture naming

Most participants found the picture naming task challenging. The mean accuracy rate was 18.78% (see Figure 2), and four participants (1 TD, and 3 ALI) were unable to correctly name any of the items. Accuracy scores were entered into a 3 (Group; TD vs ALN vs ALI) x 2 (Condition; Definition vs Context) mixed measures ANOVA. There was a significant main effect of Group, $F(2, 61) = 5.24$, $p = .008$, $\eta_p^2 = .15$, driven by the ALN group accurately naming more items than the ALI group, $p = .026$. However, the TD group did not differ from either the ALN group, $p = .149$, nor the ALI group, $p = .528$. As expected, there was no main effect of Condition, $F(1, 61) =1.03$, $p = .315$, η_p^2 .02, nor a Group x Condition interaction, $F(2, 61) = .48$, $p = .484$, $\eta_p^2 = .02$, suggesting that presentation mode did not influence phonological learning.

INSERT FIGURE 2 HERE

Receptive semantic knowledge: Word to picture matching accuracy

Participants found recognising new words considerably easier than naming them, and 29.69% of participants performed at ceiling for the words taught in the definition condition (TD: 37.93%, ALN: 38.89%, ALI: 5.88%) and 42.19% performed at ceiling in the context condition (TD: 44.83%, ALN: 44.44%, ALI: 35.29%). Twenty percent of the sample scored at ceiling in both conditions (TD: 24.13%, ALN: 27.78%, ALI: 5.88%) and the group differences were not significant, χ^2 (2) = 3.67, $p = .160$. After excluding these participants, a 3 (Group) x 2 (Condition) mixed measures ANOVA indicated that there was a marginal main effect of Group, $F(2, 48) = 2.84$, $p = .067$ $\eta_p^2 = .11$, driven by the lower scores of the ALI group relative to their TD peers ($p = .054$). There was also a main effect of Condition, with children achieving significantly higher accuracy scores for words taught in the context relative to definition condition, although the effect size was small, $F(1, 48) = 6.91$, $p = .011$, $\eta_p^2 = .13$ (see Figure 3). There was no Condition x Group interaction, $F(2, 48) = 2.28$, $p = .110$, $\eta_p^2 = .09$.

INSERT FIGURE 3 HERE

Expressive semantic knowledge: Semantic retrieval

Semantic retrieval accuracy

One child with ALI refused to complete this task for the context condition so they were excluded from the 3 x 2 mixed measures ANOVA analyses. For the other participants, there was a significant main effect of Group, $F(1, 60) = 10.04$, $p < .001$, $\eta_p^2 = .25$. The TD and ALN groups achieved significantly higher scores than the ALI group, $p < .001$ and $p = .001$ respectively, but the TD and ALN groups did not differ, $p = .972$. There was also a significant main effect of Condition, $F(1, 60) = 33.58$, $p < .001$, $\eta_p^2 = .36$, with higher scores in the definition condition than in the context condition, see Figure 4. This suggests that participants were able to provide more complete and coherent responses when provided with definitional information rather than contextual information, despite similar information being conveyed in both conditions. The Group x Condition interaction was not significant, $F(2, 60) = 1.56$, $p = .218$, $\eta_p^2 = .05$.

Semantic retrieval errors

In each condition around one third of children provided indeterminate (don't know) responses to at least one of the items in the stimuli set, but the mean number of indeterminate responses was low for all three groups in both conditions (mean = .27 – .82). Around a third of the sample also provided at least one inaccurate detail, such as describing 'palisade' as "to do with a planet" (ID 309) rather than as a plant cell. However, the mean number of inaccurate details provided was low for all three groups in both conditions (range = .21 – 1.36). A 2 (Condition) x 2 (Error Type; Indeterminate vs Inaccurate) ANOVA indicated that there were not main effects of Condition, nor Error Type, nor a Condition x Error Type interaction for either the TD, ALN or ALI group, all $F < 2.71$, all $p > .112$.

INSERT FIGURE 4 HERE

Discussion

This study examined whether children with ASD are able to learn phonological and semantic aspects of new vocabulary when meaning must be inferred from the surrounding linguistic context, and compared performance to learning from explicit definitions. We also considered whether concomitant language impairment in ASD influenced learning in these different conditions. Children with ASD were able to learn from context, but they, and their TD peers, acquired greater expressive semantic knowledge from definitional information. Overall, the ALI group learnt less than their peers.

Phonological learning was assessed through a picture naming post-test. All groups found this task challenging and the mean accuracy rate was only 20%, though this degree of naming accuracy is consistent with other studies (e.g. Lucas & Norbury, 2014; Mengoni, Nash & Hulme, 2013). Phonological learning can be an area of strength for children with ASD (Lucas & Norbury, 2014; Norbury et al., 2010), but the current study indicates this may only be the case for children with ALN. This aligns with evidence that children with ALI perform more poorly than their ALN peers on standardised phonological tasks, such as phonological awareness and phonological memory (Lindgren et al., 2009). As expected, phonological learning did not vary by condition.

Like phonological learning, proficiency of semantic learning was also associated with pre-existing language ability. The children with ALN did not differ from their TD peers on either semantic learning post-test, whereas the ALI group attained lower accuracy scores than both the TD and ALN groups on the semantic retrieval task. This suggests that the children with ALI were struggling to extract and recall relevant information. Future research could examine whether this was due to difficulty understanding the detailed semantic information, or difficulty verbally formulating sentences to convey detail. We also examined indeterminable and inaccurate response rates, but on this measure there were no group differences. Therefore whilst the children with ALI lacked the detailed knowledge of their peers, they did understand the 'gist' of the content, and importantly they were not making incorrect inferences.

We hypothesised that the extraction of information would be especially challenging in the context condition for children with ASD, but this was not the case. Instead, in the picture matching task there were higher accuracy scores for words taught in the context relative to definition condition for all three groups, although given the high rates of performance at ceiling caution needs to be applied when interpreting these results. In contrast, on the semantic retrieval task all three groups provided more semantic information in the definition than context condition. Critically, greater detail was not provided to the participants in the definition condition during the learning phase; instead both conditions contained similar core information. This finding therefore lends support to The National Institute of Child Health and Development's (Armbruster, Lehr, & Osborn, 2010) recommendation that at least some vocabulary should be explicitly taught, particularly concepts that are complex and not part of a child's everyday experience. Arguably Science vocabulary falls within this remit. However, potentially the definitional learning condition in this study provided a more direct model of how to answer the definition probe, and therefore further investigation is warranted.

However, it is not feasible for all words to be taught explicitly, and children will be required to learn some vocabulary inferentially Before concluding that children with ASD will be able to do this as effectively as their peers, it is important to take into consideration task characteristics. The employed learning paradigm largely relied on cohesive inferences (which maintain links within the text), and these are less challenging than elaborative inferences (which add information not explicitly stated within the text), especially for children with ASD (Norbury & Bishop, 2002). Potentially group differences would have been more evident if the context condition required elaborative inferences to be made. Additionally, the information provided for each target word was contained within 1-2 sentences. Inferencing deficits in individuals with ASD are more pronounced when the stimuli are passages (Lucas & Norbury, 2015; Norbury & Nation, 2011) relative to vignettes (Saldaña & Frith, 2007). Children with ASD may therefore exhibit greater difficulties when required to infer the meaning of new words from longer sources. Factors influencing the ability of children with ASD to learn new words from context should therefore be investigated more thoroughly.

Implications and future research

This study provides the first evidence that children with ASD acquire more detailed expressive semantic knowledge of Science terminology when the items are presented with definitional information, rather than when the meaning must be inferred from context. This is also the case for their TD children. Educational practitioners should therefore take presentation modality into consideration when designing teaching materials.

However, notably the children with ALI acquired less phonological and semantic information than their TD and ALN peers. Future research could consider whether their rate of learning is in-line with non-autistic peers with LI, and/or younger language matched typically developing children. From a practical, educational perspective, potentially children with ALI may be able to gain deeper knowledge of new words with increased exposure; this results in greater mastery of taught words for TD children (Jenkins, Stein, & Wysocki, 1984; Stahl & Fairbanks, 1986) and non-autistic children with LI (Kan & Windsor, 2010). Alternatively (or additionally), it may be that introducing a smaller number of words to be learned and using a scaffolded approach may help to circumvent verbal working memory impairments (Nagy & Townsend, 2012). For example, it may be of benefit to present the spoken word with low level semantic information (e.g. categorical data) and ensure this information is consolidated before providing more detailed semantic information.

The current study assessed immediate learning, but in order for acquired information to be truly beneficial, it needs to be retained and utilisable at a later date. A period of consolidation, especially one involving sleep, improves recognition and recall of newly trained words for neurotypical children and adults (Brown, Weighall, Henderson, & Gaskell, 2012; Henderson, Weighall, Brown, & Gaskell, 2012; Tamminen, Payne, Stickgold, Wamsley, & Gaskell, 2010). However, the majority of children with ASD experience sleep abnormalities (Richdale, 1999) such as restless sleep and frequent waking (Goodlin-Jones, Tang, Liu, & Thomas, 2008; Williams, Sears, & Allard, 2004), and there is preliminary evidence that children with ASD have aberrant word consolidation (Henderson et al., 2014). It would therefore be of interest to assess whether vocabulary consolidation is impacted by teaching method for children with ASD, and whether mode of teaching impacts the ability to actually use, rather than solely recall, information.

Conclusion

Children with ASD are able to learn new vocabulary from linguistic context. However they, and their TD peers, acquire more detailed semantic knowledge when definitional information is provided. Yet there are too many words children need to learn for them all to be taught individually. A priority for future research is therefore to determine which vocabulary most likely requires explicit instruction (e.g. Science words) and how best to teach children word learning strategies they can utilise independently. Children with ALI do not learn new vocabulary as efficiently as their TD and ALN peers, and therefore likely need additional tuition.

Compliance with Ethical Standards

Conflict of Interest: The authors declare that they have no conflict of interest.

Ethical approval: All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: Informed consent was obtained from all individual parents/guardians of the children included in this study, and assent was obtained from all individual children in this study.

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Appendix

Stimuli characteristics

Stimuli	Age of acquisition	Familiarity	Imageability	Number of Syllables	Number of letters
Set A					
catalyst	15.70	8.53	3.40	3.00	8.00
hippocampus	16.43	8.20	4.87	5.00	11.00
lantana	17.67	0.27	0.20	2.00	7.00
dynamo	15.88	6.33	3.73	3.00	6.00
ratite	16.25	0.33	0.60	2.00	6.00
taxa	16.50	1.87	1.00	2.00	4.00
pupa	14.86	5.10	5.40	2.00	4.00
stomata	17.00	5.30	4.20	3.00	7.00
troposphere	16.86	3.20	2.90	3.00	11.00
mastodon	19.50	2.40	1.60	2.00	8.00
Average	16.66	4.15	2.79	2.70	7.20
Set B					
pantograph	15.00	0.47	0.40	3.00	10.00
palisade	15.50	2.47	1.60	3.00	8.00
parasite	10.87	8.60	6.67	3.00	8.00
tropism	14.00	0.87	0.07	3.00	7.00
rabid	10.50	6.27	4.60	2.00	5.00
cornea	11.47	8.67	6.87	3.00	6.00
miscible	14.20	2.40	1.87	3.00	8.00
photon	15.20	5.40	2.80	2.00	6.00
smolt	23.00	0.70	0.50	1.00	5.00
torpor	17.25	2.10	1.50	2.00	3.00
Average	14.70	3.79	2.69	2.50	6.60

Table 1

Descriptive statistics for typically developing (TD) children and children with autism spectrum disorder with (ALI) and without (ALN) language impairment

Variable	TD Mean (SD)	ALN Mean (SD)	ALI Mean (SD)	Test statistics
Chronological age (years)	11.29[a] (11.08)	11.58[a] (1.93)	11.23[a] (2.00)	$F = .25$, $p = .779$
Gender Male	16	14	13	$\chi^2 = 3.32$, $p = .174$
Female	13	4	4	
WASI matrix reasoning[1]	50.93[a] (7.59)	50.53[a] (7.66)	42.06[b] (10.25)	$F = 6.46$, $p = .003$, $\eta^2 = .19$
Receptive one-word picture vocabulary test[2]	102.07[ab] (12.99)	107.06[a] (15.68)	93.75[b] (11.23)	$F = 4.06$, $p = .024$, $\eta^2 = .16$
CELF recalling sentences[3]	10.57[a] (3.82)	10.83[a] (2.62)	4.06[b] (1.85)	$F = 31.42$, $p < .001$, $\eta^2 = .58$
Social communication questionnaire[4]	3.17[a] (3.04)	21.33[b] (7.75)	25.56[b] (6.23)	$F = 43.90$, $p < .001$, $\eta^2 = .75$

[a] Groups with the same superscript do not differ when p=.05.

Note: [1] t-score with normative mean of 50, SD = 10, [2] standard score with normative mean of 100, SD = 15, [3] scaled scores with normative mean of 10, SD = 3. [4] Raw score, scores >15 indicative of ASD.

Table 2

Word properties

Property	Set 1 Mean (SD)	Set 2 Mean (SD)	*t*-value	*p* value
Age of Acquisition	16.67 (1.26)	14.70 (3.65)	1.61	.125
Familiarity	4.15 (3.01)	3.80 (3.19)	.26	.799
Imageability	2.79 (1.84)	2.69 (2.52)	.10	.919
Number of letters	7.20 (2.44)	6.90 (1.60)	.33	.749
Number of syllables	2.80 (.63)	2.50 (.70)	1.00	.331

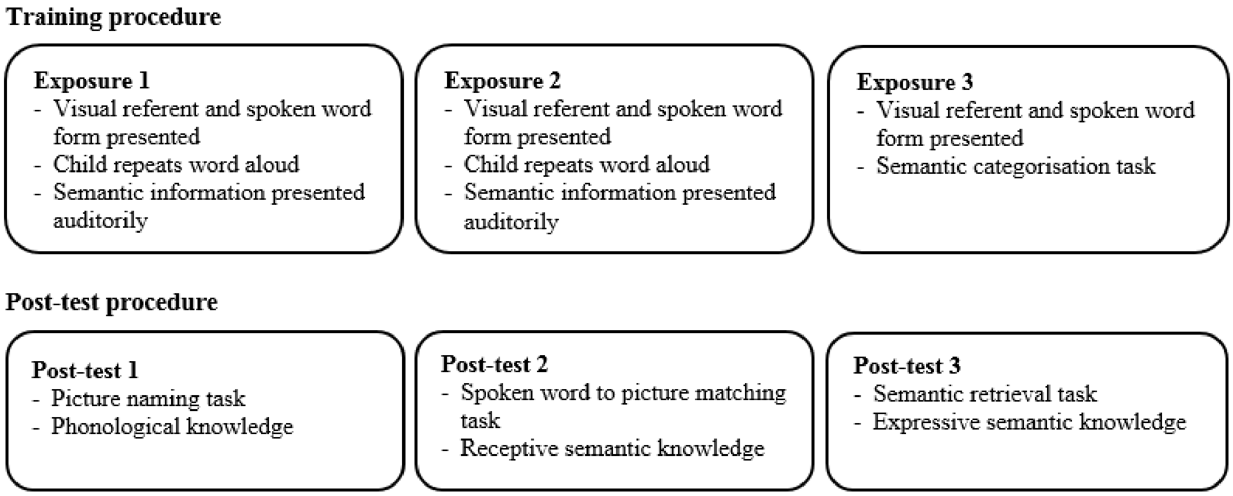

Figure 1. Experimental task procedure

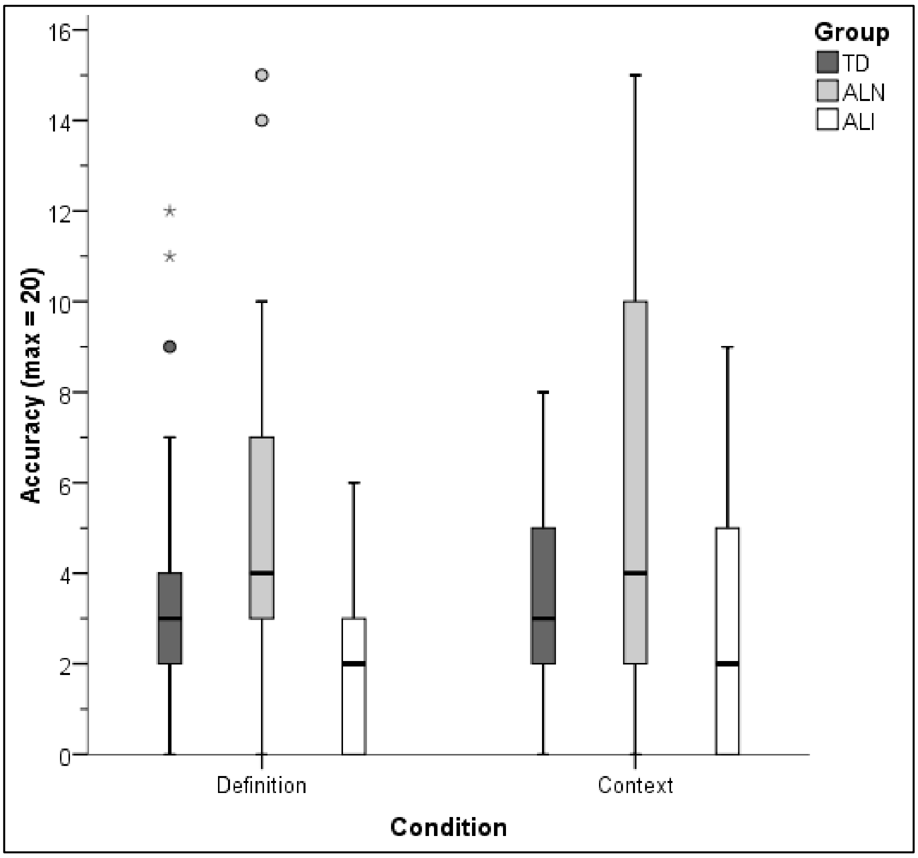

Figure 2. Mean accuracy on the picture naming post-test.

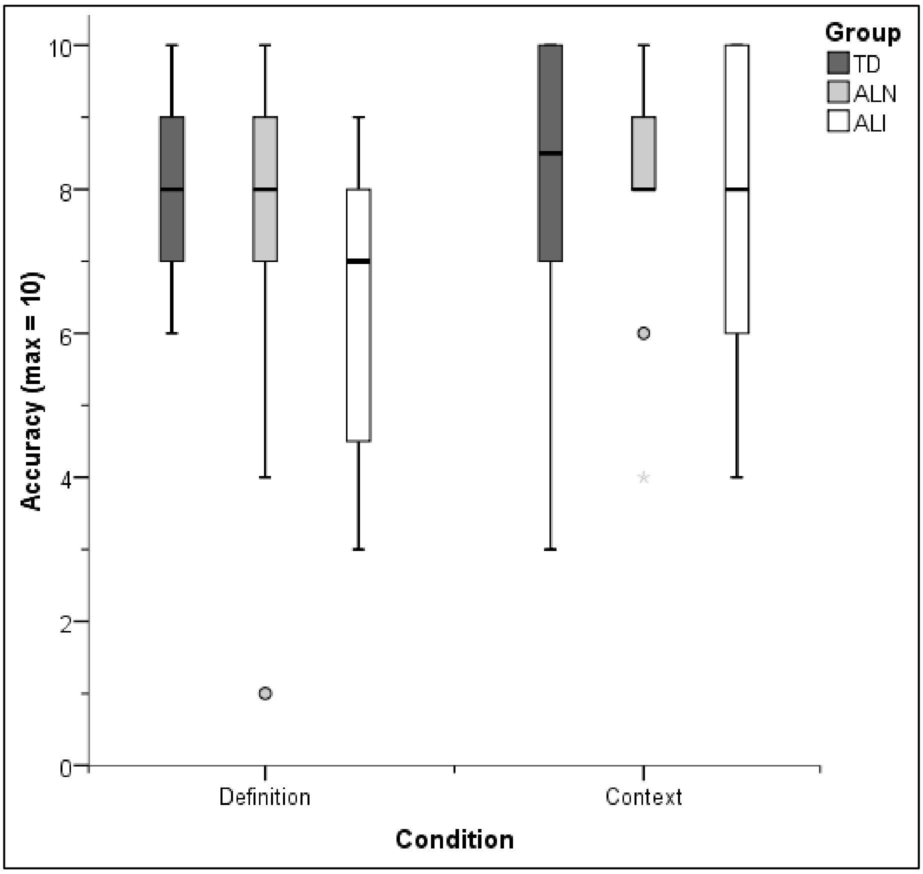

Figure 3. Mean accuracy on the spoken word to picture matching post-test.

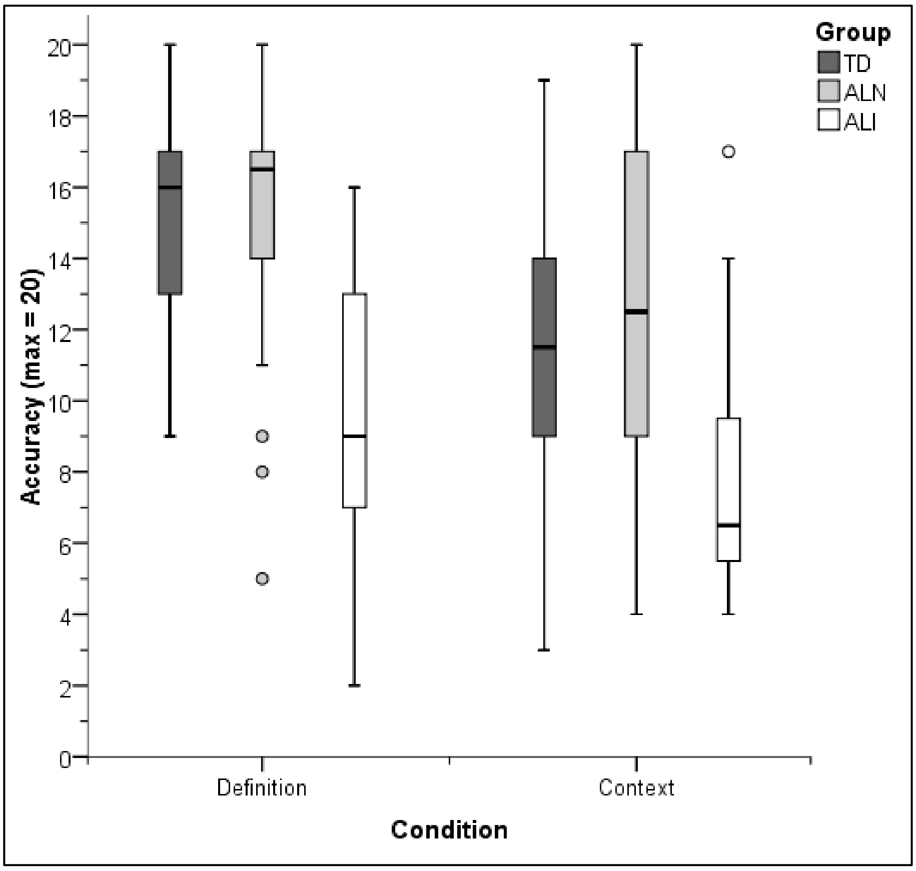

Figure 4. Mean accuracy on the semantic retrieval post-test.