SCIENTIFIC Publishing Limited

Neurolinguistic Communication Intervention

https://ojs.ukscip.com/index.php/nci

Article

Mandarin-speaking monolingual autistic children can learn and retain foreign language words: A longitudinal study

Xin Kang[1 2 3*], Yaqian Zhang[1 2 3], Ning Ding[1 2 3], Xiyu Hu[1 2 3], Xuanchi Chen[1], Qiutong Liu[1]

1 School of Foreign Languages and Cultures, Chongqing University, Chongqing, China

2 Research Centre for Language, Cognition and Language Application, Chongqing University, Chongqing, China

3 Key Laboratory of Hearing, Speech, and Cognition of Chongqing Municipal Health Commission, Chongqing, China

ABSTRACT

Bilingualism has long been linked with enhanced cognitive benefits, but parents of autistic children are often advised to use one language. One reason might be that there is limited evidence on the foreign language learning abilities of autistic children. This study investigated English word learning among monolingual Mandarin-speaking autistic and typically-developing (TD) children using a longitudinal design. Participants were taught 48 English object names in a classroom-like setting over eight weekly sessions. Before starting the program, participants completed a pre-test to calculate the percentage of target words they could identify and translate from English to Chinese. To measure their short-term learning outcomes, they completed an immediate learning test at the end of each session and a delayed test at the beginning of the session the week after. Long-term retention was measured using final tests at one- and five- weeks after the learning program ended. Although autistic children showed slower weekly gains in word recognition, they achieved comparable long-term retention to TD peers, with no significant group differences in final test performance. Critically, the learning outcomes for autistic children were strongly and pervasively correlated with their amount of prior L2 exposure, whereas this relationship was largely absent in TD children. These findings demonstrate that autistic children can effectively learn and retain L2 words, challenging recommendations for monolingualism. Future studies should explore more complex linguistic domains, such as grammar and pragmatics, to further understand foreign language acquisition among autistic individuals.

Keywords: autism spectrum disorder, second language acquisition, word learning, bilingualism, foreign language

1. Introduction

Autistic children demonstrate heterogeneity in their language abilities (Henderson et al., 2014; Larson et al, 2022; Tager-Flusberg, 2015; Wittke et al., 2017). Despite impairment in social communication and interaction (Arunachalam & Luyster, 2018; Larson et al., 2022), some of them were reported to show comparable language abilities as their typically developing (TD) peers (Ferman, 2021; Kjelgaard & Tager-Flusberg, 2001; Wittke et al., 2017). As inclusive education gaining increasing attention worldwide, more autistic children are enrolled in mainstream schools (An et al., 2018; Li et al., 2022; Zhou et al., 2020) where they are expected to learn a foreign language (L2) alongside their TD classmates (Hu et al., 2023).

This reality stands in stark contrast to the long-standing clinical advice given to parents to raise their autistic children in a monolingual environment (Baker, 2013; Hudry et al., 2018; Jegatheesan et al., 2010). This recommendation stems from a now-outdated concern that bilingual exposure could cause confusion, impose an extra cognitive burden, or exacerbate difficulties in autistic children (Beauchamp & MacLeod, 2017; Gonzalez-Barrero & Nadig, 2018; Yu, 2013).

However, a growing body of evidence challenges this advice. Empirical studies have shown that some bilingual autistic children did not lag behind their monolingual autistic peers in language development (Beauchamp et al., 2020; Drysdale et al., 2015; Hambly & Fombonne, 2012;). Recent studies even revealed that bilingual autistic children showed advantages compared to monolingual non-autistic children in certain areas, such as focus production (Ge et al., 2024), expressive vocabulary size (Petersen et al., 2012), functional vocabulary size (Dosi & Sotiriadis, 2020), verbal fluency (Gonzalez-Barrero & Nadig, 2017), narrative skills (Peristeri, 2020), and cognitive capacities (Peristeri, et al., 2024), echoing the potential cognitive and linguistic benefits associated with bilingualism in the general population (Bialystok et al., 2012; Bialystok, 2024).

2. Word learning among autistic children

A critical domain for examining foreign language learning is word learning, which is a fundamental component of language development (Beauchamp & MacLeod, 2017; Davis et al., 2016; Hashim et al., 2022; Patael & Diesendruck, 2008; Sukenik & Tuller, 2023). Research in first language (L1) acquisition reveals a complex profile in autistic children. On the one hand, autistic children showed similar vocabulary developmental stages as their TD peers (Ferman, 2021; Gladfelter & Goffman, 2018; Hartley et al., 2019). For example, like their TD peers, autistic children exhibited typical noun-dominant early lexicons (Rescorla & Safyer, 2013). Autistic children could also apply principles such as "mutual exclusivity" (Mathée-Scott et al., 2021; Rothwell et al., 2024) and use social cues to map words to objects (Luyster & Lord, 2009). On the other hand, autistic children often learn new words less efficiently (Ferman, 2021; Hartley et al., 2019, 2020) and struggled with long-term retention (Kover & Ellis-Weismer, 2014). They also have smaller sizes of receptive and expressive vocabulary than their TD peers (Boucher, 2012; Charman et al., 2003; Hyter, 2007; Kjelgaard & Tager-Flusberg, 2001; McGregor et al., 2012), particularly for abstract nouns and pronouns (Perovic et al., 2013; Tager-Flusberg & Caronna, 2007).

Much of this evidence comes from highly controlled novel-word learning paradigms (e.g., Franken et al., 2010; Hartley et al., 2020; Luyster & Lord, 2009; Rothwell et al., 2024; Tenenbaum et al., 2014). While these laboratory-based studies provide valuable insights but often lack ecological validity. Furthermore, many of these studies have focused primarily on immediate recall (Ferman, 2021; Harper-Hill et al., 2014; Tenenbaum et al., 2014) or used short retention intervals ranging from 5 minutes (Hartley et al., 2020) to 24 hours (Henderson et al., 2014) between learning and testing, which leaves a critical research gap in our understanding of long-term retention. While a few longitudinal studies have examined retention (e.g., Bosseler & Massaro, 2003; Norbury et al., 2010), they are typically limited by very small numbers of taught words or the absence of a TD comparison group, making it difficult to gauge autistic children's learning relative to their peers. For instance, Bosseler and Massaro (2003) taught real vocabulary items to autistic children using a computer-animated agent named *Baldi* over six months. 84 vocabulary lessons with 559 distinct vocabulary words drawn from school curricula, books, and image banks were delivered via a

multimodal interface combining synthesized speech, written labels, and visual images. Learning outcome was assessed through immediate tests and a follow-up assessment 30 days later. They found that autistic children were able to learn new words, and 91% of the newly learned vocabulary was retained one month later. Norbury et al. (2010) compared 13 autistic children and 13 TD peers who were matched on age, non-verbal IQ, and receptive vocabulary on novel word learning and retention. Participants learned four novel words (e.g., *akidit*, *dentip*) by six exposures. Then, using a computerized eye-gaze paradigm, a woman directed attention to the target object in biased trials (three times in a neutral condition and three in a biased condition). Accuracy rates and response times were recorded during the learning process. Three types of vocabulary tasks were administered immediately and again four weeks later: object naming, picture identification, and defining the target objects. Results showed that autistic children initially outperformed their peers in mapping phonological forms to novel referents, but this advantage diminished over time, whereas TD children showed sustained retention.

Critically, research on L2 word learning in autistic children is even limited (Gonzalez-Barrero & Nadig, 2018; Hambly & Fombonne, 2014; Petersen et al., 2012). The few existing studies, often single-case or small-group designs (e.g., Alemi et al., 2015; Hu et al., 2023; Zohoorian et al., 2021), confirm the potential for L2 acquisition but are severely limited by minimal sample sizes and a lack of control groups. Consequently, fundamental questions about whether autistic children can learn and retain L2 vocabulary as effectively as their TD peers in a naturalistic, classroom-based context remain unanswered. For example, Alemi et al. (2015) investigated the effectiveness of humanoid robots in teaching English words to four Iranian autistic children. By comparing their scores at four timepoints: pretest, mid-test, immediate posttest, and delayed posttest (two weeks after learning), this study revealed significant improvements in children's English word knowledge, with learning effects maintained after two weeks. Similarly, Zohoorian et al. (2021) examined the effectiveness of the Picture Exchange Communication System (PECS) in English word instruction for two Iranian autistic children. The learning program consisted of 15 weekly sessions targeting 45 words, with repeated measurement showing progressive improvement in participants' vocabulary knowledge. In another study, Hu et al. (2023) taught English vocabulary to three Mandarin-speaking preschool autistic children. They found that these children could learn English words in a small-group training.

Taken together, the existing research indicates that autistic children can acquire new words, but critical questions about their L2 learning abilities in the real-world remain answered. There are mainly three research gaps. First, many of these studies focused primarily on L1 word learning and used immediate recall with fewer studies examining long-term retention. Second, although some studies employed longitudinal designs, they were mostly conducted in laboratory settings, which may not fully reflect the dynamics of group-based instruction that mirror mainstream classrooms. Third, while some recent studies have begun to explore L2 vocabulary learning in participants, most of these studies had small sample sizes and lacked comparison groups.

To address these limitations, the present study implemented a 13-week longitudinal L2 learning experiment to mirror a mainstream classroom. We investigated learning outcomes by measuring their performance at the end of the current session and a week later. Two post-tests were used as final tests for overall learning outcomes at the 9th week and 13th week. In addition, we examined how demographic factors and autism spectrum disorder (ASD) symptoms may influence participants' learning outcomes. We focused on three research questions:

Do Mandarin-speaking autistic children demonstrate comparable L2 word learning outcomes as their TD peers?

Can Mandarin-speaking autistic children retain L2 words as their TD peers over short and long-term intervals?

To what extent do factors such as prior L2 exposure and nonverbal IQ influence their L2 word learning outcomes?

3. Methods

3.1 Participants

40 Mandarin-speaking children participated in the study, including 25 autistic children and 15 TD children. Autistic participants were recruited via a local autism parent support group, while the TD participants were recruited through flyers distributed in local areas. The two groups were matched on the onset time for learning English at school. None of the participants were routinely exposed to English outside school. ASD status was confirmed with the administration of the Autism Diagnostic Observation Schedule 2nd Edition (ADOS-2; Lord et al., 2012). Nonverbal IQ was assessed using the Test of Nonverbal Intelligence 4th Edition (TONI-4; Brown et al., 2010) or Primary Test of Nonverbal Intelligence (PTONI; Ehrler & McGhee, 2008) based on participants' chronological age. 37 participants above 6-year-old completed TONI-4 and 3 below 6-year-old completed PTONI. Parents completed questionnaires about demographic information. The study was conducted with the approval of the ethics committee of the university. Written informed consent was obtained from parents or caregivers of all participants.

Eleven out of the 40 participants were excluded for data analysis. 3 autistic children missed more than three sessions out of eight sessions during the learning phase. 5 autistic children and 3 TD did not participate the posttest at the 9th week or the 13th week. Furthermore, 2 autistic children did not meet the diagnostic criteria for ASD based on ADOS-2. Thus, a total of 15 autistic children (*M* age = 11.00 years, *SD* = 2.66 years) and 14 TD children (*M* age = 6.57 years, *SD* = 1.19 years) were included in data analysis. Detailed characteristics of the participants were summarized in Table 1. Despite careful matching, the autistic group were significantly older ($p < .001$) but with lower scores on nonverbal IQ ($p < .001$) than TD peers.

Table 1. Demographic characteristics of participants.

	ASD (*n* = 15)	TD (*n* = 14)	Group difference
	M (*SD*)	*M* (*SD*)	*p*
Age (years)	11.00 (2.66)	6.57 (1.19)	<.001
ESL (years)	1.14 (1.62)	0.61 (0.88)	.683
Family SES	45.43 (16.86)	51.54 (6.56)	.730
ADOS-2 Total Score[a]	8.42 (1.31)	-	-
Nonverbal IQ[b]	95.47 (18.54)	123.93 (13.87)	<.001
Pretest			
Translation acc (%)	44.60 (20.90)	38.44 (13.97)	.418
Identification acc (%)	51.75 (21.57)	44.56 (13.32)	.325

Note. Group differences were assessed via nonparametric Mann-Whitney *U* tests. [a]ADOS-2 comparison severity score labels are as follow: 0-2 = "minimal-to-no evidence," 3-4 = "low," 5-7 = "moderate," 8-10 = "high." [b]Non-verbal IQ was measured by TONI-4 or PTONI (3 participants below 6-year-old).

3.2 Materials

The pretest was conducted at the 1st week to measure the baseline knowledge of the 48 words. During the 8-week learning phase, participants learned 6 words per week and their learning data was recorded. Two tasks were designed and conducted immediately after each learning session and one week later. First, they completed a picture *Identification* task. Participants were asked to identify the object out of four choices with one correct answer and three distractors, including a semantically related object, a phonologically related object, and an unrelated object. The position of the target object has been counterbalanced. Then, they completed a *Naming* task in which they were asked to name objects in English. Testing materials in this task were colored pictures of the target words. Two post-tests were designed to examine the overall learning outcomes at the 9th week and the 13th week. First, participants were asked to translate a target word from English to Chinese (*Translation*). Then they were asked to identify the picture corresponding to that word (*Identification*) from a testing card. They were tested for 48 words individually in a randomized order. Accuracy rates were calculated as outcome measures.

3.3 Procedure

The current study was a longitudinal design lasting 13 weeks. It had 4 phases (see Figure 1), including a pretest (Week 1st before learning), a word learning phase (from Week 1st to Week 8th, 90 minutes per session), a post-test (Week 9th), and a follow-up post-test (Week 13th).

This study began with a pretest in the first week to measure the baseline of participants' L2 vocabulary knowledge. The pretest employed two tasks: *Translation* and *Identification*. For the *Translation* task, participants were presented with the sound of target words in L2 (English) by the experimenter and were required to provide the corresponding translation in their L1 (Chinese). Then, for the *Identification* task, participants viewed a set of pictures (including images of the target item and three distractors) and were asked to identify the target object. Participants were tested for the whole list of words. Then, a two-month (one session per week with each session lasting 90 minutes) learning phase started. During this phase, participants learned 6 words per week in a classroom-like settings. Each class had 6-8 students with an instructor and two teach assistants. To facilitate effective learning, instructional materials were carefully selected to provide scaffolding and cultivate interest. Target words were learned by presenting real objects, toy objects, jigsaw puzzle pieces, pictures, or stickers. These materials were integrated into games such as role-play and coloring activities, creating an interactive environment that facilitated active participant engagement. At the end of each learning session, accuracy rates for immediate *Identification* and *Naming* tests were calculated (Time 1: immediate test), which required participants to identify and name the target words they had learned during the current session, respectively. Participants were also tested for their short-term retention using the *Identification* and *Naming* tasks of the target words learned during the previous session when the next session started (Time 2: delayed test). At the 9th week and then the 13th test, *Translation* and *Identification* tasks used at the pretest were readministered. The purpose of the post-tests was to measure the overall learning outcomes. Standardized tests were administered at the 13th week, including ADOS-2 (Lord et al., 2012), TONI-4 (Brown et al., 2010) or PTONI (Ehrler & McGhee, 2008).

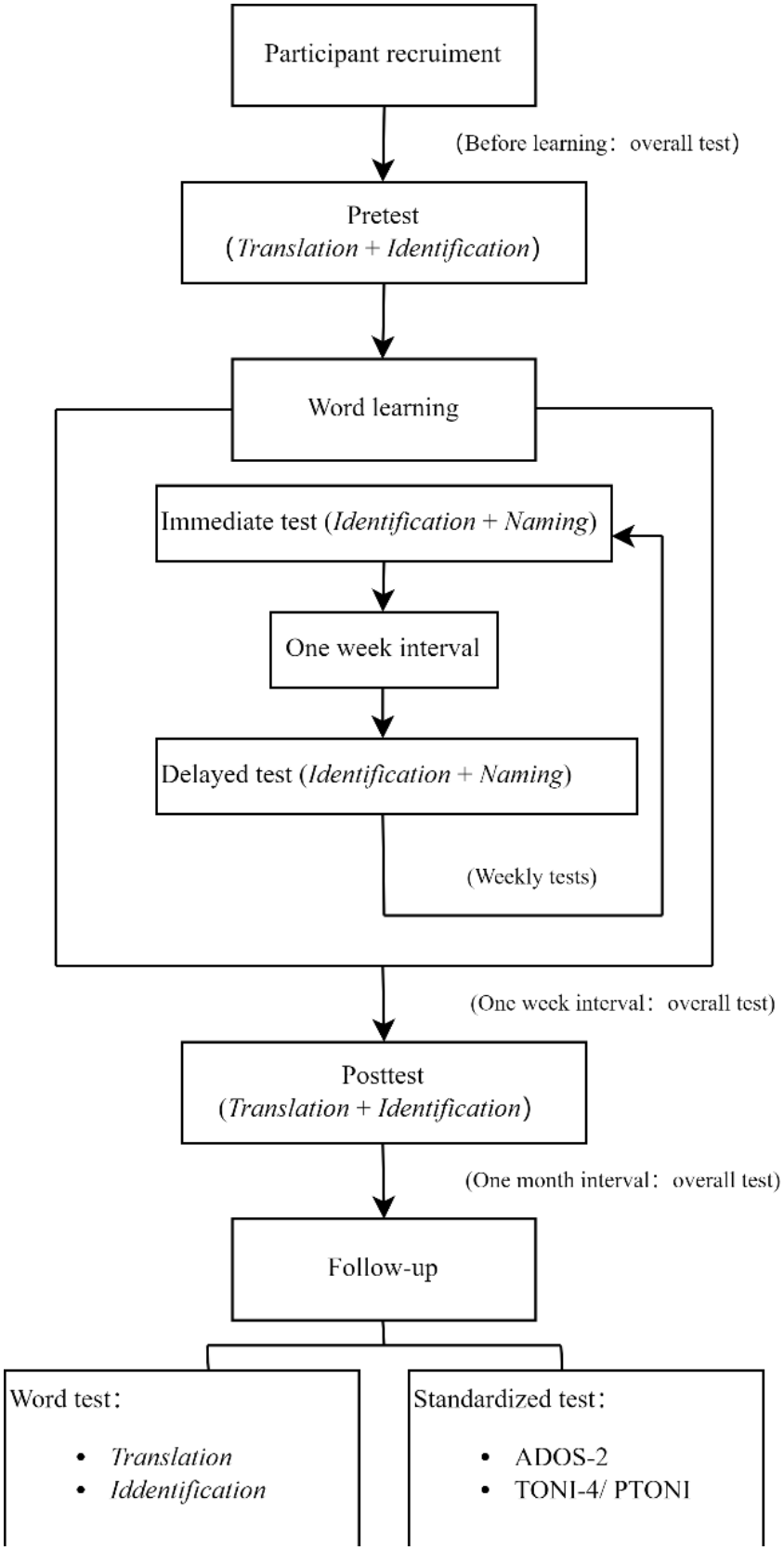

Figure. 1 Experimental procedure illustrating the four main phases: pretest, weekly learning with immediate and delayed tests, overall learning with posttest and follow-up.

3.4 Data processing

Nonparametric statistical methods were used for data processing given our small sample sizes. First, Wilcoxon signed-rank tests were used to compare differences between accuracy rates at Time 1 (Immediate test) and Time 2 (Delayed test). Meanwhile, Wilcoxon rank-sum tests were applied to compare performances between autistic and The TD groups. Then, the overall learning outcomes concerning L2 vocabulary growth and long-term retention have been analyzed. Changes across the three time points (Pretest, Posttest, and Follow-up test) were examined using Friedman tests within each group, with post hoc comparisons conducted using Wilcoxon signed-rank tests with BH correction. Then, Wilcoxon rank-sum tests were conducted for between-group comparisons for each time point. Finally, Spearman correlation analyses were conducted to explore the relationships between word learning outcomes and several potential impact factors: (a) amount of English exposure, (b) family socioeconomic status, (c) autism severity (as measured by the ADOS-2), and (d) nonverbal IQ (as measured by the TONI-4 or PTONI).

4. Results

4.1 *Weekly learning outcomes*

Figure 2 illustrates the average accuracy rates for the *Identification* and *Naming* tasks at Time 1(Immediate test) and Time 2 (Delayed test). Wilcoxon signed-rank tests revealed that the autistic group did not show significant differences between Time 1 and Time 2 for *Identification*: $p = .440$ and *Naming* ($p = .304$) tests. While in the TD group, participants performed better in the *Naming* test at Time 2 than at Time 1 ($p = .021$). Nonetheless, they did not show significant difference in the *Identification* test between Time 1 and Time 2 ($p = .081$). When comparing across tasks, as expected The TD group performed significantly better in *Identification* than in *Naming* at both Time 1 ($p < .001$) and Time 2 ($p < .001$). Similar patterns were found for autistic participants that they performed better in *Identification* than in *Naming* at both Time 1 ($p < .001$) and Time 2 ($p < .001$). Between-group comparisons using Wilcoxon rank-sum tests found that TD children performed significantly better than autistic children at Time 1 ($p < .001$) as well as at Time 2 ($p = .017$) for *Identification*. No significant group differences were found at either Time 1 ($p = .315$) or Time 2 ($p = .673$) for *Naming*.

4.2 *Overall learning outcomes*

Table 2 presents the mean accuracy rates and standard deviations for *Translation* and *Identification*. Friedman tests were conducted separately to compare participants' performance across three time points (Pretest, Posttest, and Follow-up test). Results revealed significant learning outcomes in both autistic and The TD groups (*Translation*: $\chi^2 = 20.86$, $p < .001$ in ASD; $\chi^2 = 23.10$, $p < .001$ in TD; *Identification*: $\chi^2 = 21.57$, $p < .001$ in ASD; $\chi^2 = 25.17$, $p < .001$ in TD). To examine the performance at different timepoints, subsequent analyses were conducted separately within groups and results were displayed in Figure 3.

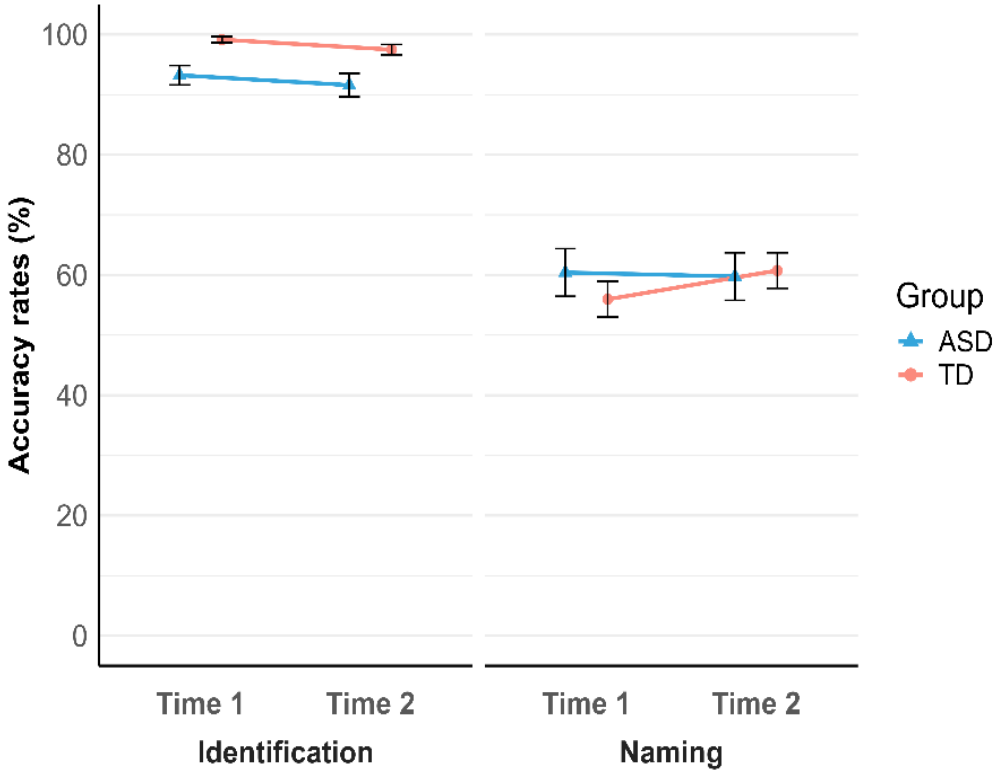

Figure. 2 Weekly learning outcomes. Time 1 = Immediate Test. Time 2 = Delayed Test.

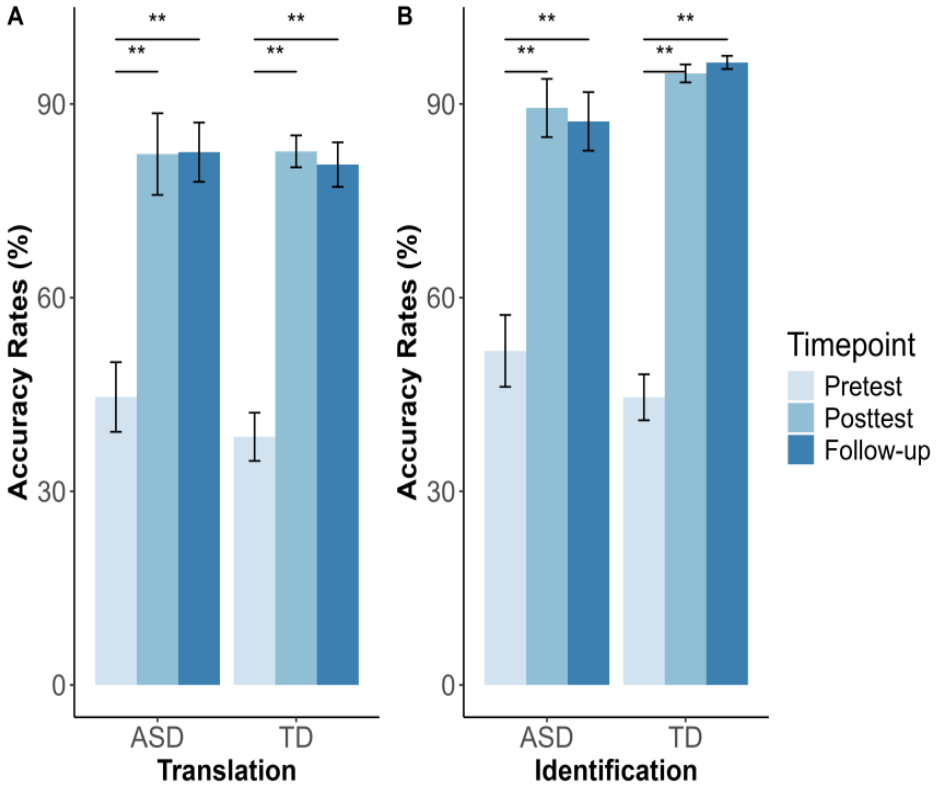

Figure. 3 Overall learning outcomes

In the autistic group, post hoc analysis using Wilcoxon signed-rank tests revealed significant differences between pretest and posttest in both *Translation* (p = .003) and *Identification* (p = .003). Significant differences were also observed between pretest and follow-up (Translation: p = .002; Identification: p = .002). However, no significant differences were found between posttest and follow-up (*Translation*: p = .414; *Identification*: p = .834). For the TD group, post hoc analysis exhibited similar results to the autistic group, such that significant differences were found between pretest and posttest for both *Translation* (p = .002) and *Identification* (p = .002)between pretest and follow-up (Translation: p = .002; Identification: p = .002). No significant differences were detected between posttest and follow-up (*Translation*: p = .513; *Identification*: p = .140). Wilcoxon rank-sum tests revealed no significant differences between the autistic group and the TD group for both tasks (*Translation* and *Identification*) at either posttest or follow-up (all p > .05).

4.3 *Correlation analysis*

We further conducted Spearman's correlation analyses (see Table 3 and Table 4) for autistic and The TD groups separately to assess the relationships between L2 learning outcomes and potential impact factors: the amount of English exposure, family socioeconomic status (family SES), nonverbal IQ, and ASD severity (the autistic group only).

Regarding the weekly performance (Table 3), English exposure duration showed pervasive correlations with learner's performance in two tasks (*Identification*: both p < .001; *Naming*: both p < .001) among the autistic children. Nonverbal IQ also exhibited similar correlation patterns (*Identification*: p = .002 at Time 1, p = .001 at Time 2; *Naming*: both p < .001 at Time 1 and Time 2). In contrast, correlation patterns were only found between English exposure and *Naming* (Time 1: p < .001, Time 2: p = .001), and between nonverbal IQ and *Naming* (both p < .001) among TD children.

As for the overall learning performance (Table 4), results indicated that within the autistic group, the amount of English exposure exhibited significant positive correlations with both tasks across time (*Translation*: posttest p = .013, follow-up p = .026; *Identification*: posttest p= .008), except for the follow-up *Identification* (p = .065). For nonverbal IQ, we found it was significantly correlated with learners' performance at only follow-up in *Translation* (p = .029). However, within The TD group, no correlation between the amount of English exposure were observed (*Translation*: posttest p = .579, follow-up p = .492; *Identification*: posttest p = .934, follow-up p = .795). In terms of nonverbal IQ, similar correlation patterns were found for The TD group, such that nonverbal IQ was significantly correlated with participants' performances at only follow-up in *Translation* (p = .047).

5. Discussion

This study investigated whether monolingual autistic children could learn and retain L2 words. Importantly, we not only examined participants' immediate learning outcomes but also long-term retention, and explored potential factors that may influence the learning outcomes. We found that autistic children showed similar performance across Time 1 and Time 2 (Immediate test and Delayed test) in both *Identification* and *Naming* tasks. In contrast, TD children performed better in *Naming* one week after learning, suggesting that they were able to strengthen and stabilize newly learned words more effectively over a short period. This TD-specific learning gain aligns with previous research that emphasized the role of sleep in knowledge consolidation (Davis et al., 2009; Dumay & Gaskell, 2007) and mirrors prior evidence of TD-specific lexical consolidation patterns (Norbury et al., 2010). Notably, both groups consistently performed better in *Identification* than in *Naming*, illustrating the common phenomenon of receptive-expressive gap in L2 learners (Gibson et al., 2012; Keller et al., 2015; Oller et al., 2007). Between-group comparisons also revealed higher weekly *Identification* accuracy in TD children, indicating that autistic children may initially process and retain new words more slowly.

The weekly learning data revealed ASD-specific learning outcomes with consistently lower accuracy rates in *Identification* task and no consolidation effects in *Naming* task. One explanation for such observed group differences in vocabulary tasks is that the learning mechanisms of the autistic population are not atypical but inefficient (Ferman, 2021; Hartley et al., 2020). ASD may affect the efficiency of learning mechanisms by disrupting children's intake of linguistic input (Hartley et al., 2019) or affect their ability to exploit knowledge of morphophonological patterns (Ferman, 2021). Conversely, the shared receptive-expressive gap across groups underscores universal constraints in L2 lexical access, suggesting that expressive demands (e.g., phonological retrieval) pose inherent challenges regardless of diagnosis status.

Despite slower progress during weekly learning sessions, autistic children achieved comparable overall performance to TD peers in *Translation* and *Identification* tasks at the immediate and long-term follow-up posttests. Their lower weekly *Identification* accuracy suggests that short-term gains in recognizing words may be slower, yet this did not prevent long-term learning and retention. These findings indicate that, when provided with structured and supportive instruction, autistic children can successfully acquire and retain foreign language vocabulary over the long term. They likely rely on compensatory strategies such as visual supports and explicit guidance (Harper-Hill et al., 2014; Hartley & Allen, 2014; Hashim et al., 2022; Padmadewi & Artini, 2017; Skewes et al., 2020; Zwart et al., 2017). Importantly, these findings extend previous laboratory-based studies using novel word paradigms to real classroom-like group learning, demonstrating that autistic children may reach similar vocabulary learning outcomes as TD children. These results align with prior evidence challenging assumptions about bilingual limitations in autism (Alemi et al., 2015; Gonzalez-Barrero et al., 2018; Hambly & Fombonne, 2014; Hu et al., 2023; Petersen et al., 2012; Zohoorian et al., 2021) and highlight the effectiveness of structured, visually supported instruction for facilitating L2 vocabulary acquisition in autistic population.

Our analyses further revealed divergent learning mechanisms between autistic and TD children. Autistic learners showed generally consistent reliance on English exposure duration, both in weekly learning and in overall outcomes. This highlights the critical role of structured instructional input in facilitating vocabulary acquisition in the autistic group. It aligns with studies that reported the effectiveness of intensive linguistic interventions (Murdaugh et al., 2015) and the significance of language exposure in

promoting L2 lexical development among autistic individuals (Gonzalez-Barrero & Nadig, 2018; Hambly & Fombonne, 2014). In contrast, the overall outcomes of TD children were less influenced by English exposure, suggesting a greater reliance on incidental learning. This pattern is consistent with previous findings showing that autistic learners favor intentional, structured learning, whereas TD children can exploit statistical learning and contextual inference in naturalistic settings (Zwart et al., 2017).

In addition, we revealed that nonverbal IQ contributed differently between autistic and TD children. For both groups, higher nonverbal IQ was associated with better *Translation* performance at follow-up, suggesting shared cognitive constraints in long-term retention for vocabulary production. However, weekly correlations revealed task-specific effects in TD children (limited to *Naming*), whereas in autistic children, nonverbal IQ was broadly related to multiple tasks. This suggests that autistic learners may rely more on domain-general cognitive resources to compensate for less efficient linguistic processing, whereas TD children can leverage specific cognitive skills for particular tasks.

Together, our findings support a compensatory efficiency model of autism that autistic children possess the fundamental capacity for learning words in a foreign language with long-term outcomes comparable to their TD peers. However, the pathway to this success may not be typical. It is characterized by initial inefficiencies with a greater dependence on sustained and structured L2 input, and a broader reliance on domain-general cognitive resources. This indicates that autism may affect the temporal dynamics and cognitive demands of the learning process rather than the ultimate learning capacity. In contrast, TD children appear to benefit more rapidly from incidental learning mechanisms and can apply cognitive resources in a more task-specific manner. Our findings have direct practical implications. The demonstrated reliance on structured input and the achievement of long-term success within a supportive, classroom-like setting challenge recommendations to withhold L2 instruction from autistic children. Instead, educational approaches should provide explicit, sustained foreign language exposure. Strategies that reduce cognitive load and strengthen encoding—such as incorporating visual supports, consistent routines, and repeated practice—are likely to be particularly effective. By adopting such tailored approaches, educators can leverage the documented capabilities of autistic learners to make foreign language education more accessible and successful in inclusive classrooms.

Limitations and future directions

Despite its contribution to foreign language learning in autistic children, this study has some limitations. First, although our sample size and number of trials exceed many existing studies, the small sample size remains modest compared to other experimental studies. Our participants learned these English words in a small-group setting rather than a full-sized mainstream classroom. Future studies may explore L2 learning with larger cohorts in more typical mainstream classroom environments to enhance generalizability. Second, our exclusive focus on vocabulary acquisition leaves other critical linguistic domains unexplored. Future studies should examine other aspects of language learning, such as pronunciation, grammar, or conversational fluency. Third, the 13-week observation window, though surpassing the duration of most prior investigations, may not fully capture foreign language learning in the long-term. Future research may extend tracking intervals to longer periods, such as six months or years, to delineate critical learning trajectories.

6. Conclusion

In summary, our findings demonstrate that autistic children have the abilities to learn words in a foreign language in a classroom-like setting. They achieved comparable long-term retention outcomes comparable to their typically developing peers. The learning trajectory, however, is distinct. Autistic learners showed initial inefficiencies in weekly word recognition and lacked the short-term consolidation gains observed in TD children, pointing to differences in the initial encoding of new words. The relationship between L2 prior exposure and learning outcomes for autistic children demonstrates that this initial inefficiency can be effectively offset by structured, sustained instructional input. This pattern supports evidence for L2 learning in autism with tailored educational support. Our study provides crucial evidence to inform educational practice, challenging the misconception that autistic children should be excluded from foreign language learning. By demonstrating successful acquisition within a classroom-like setting, our findings advocate for inclusive L2 education and highlight the efficacy of structured, visually-supported instruction in unlocking the bilingual potential of autistic learners.

Author contributions statement

Conceptualization: YZ, XK; data curation: YZ, ND, XH, XC, QL; data analysis: YZ, XK; funding acquisition: XK, YZ; investigation: YZ, ND, XH, XC, QL; methodology: YZ; project administration: YZ, ND; resources: XK; visualization: YZ, XK; writing – original draft: XK, YZ; writing – review and editing: XK, YZ, ND, XH, XC, QL (based on CRediT: Contributor Roles Taxonomy, https://credit.niso.org/). Both authors have agreed on the final completed version. We hold accountable for all aspects of the work to ensure that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Funding details

This work was supported by National Social Science Fund of China [22CYY021], Natural Science Foundation Project of Chongqing, Chongqing Science and Technology Commission [CSTB2022NSCQ-MSX0494], the Fundamental Research Funds for the Central Universities [2023CDJSKJJ28], and Graduate Scientific Research and Innovation Foundation of Chongqing, China [CYS240018].

Acknowledgements

All the participants and their caregivers, for their enthusiastic participation and invaluable support during the learning experiment and data collection. Deepseek has been used for improving the English language.

Declaration of interest statement

The authors declared no potential conflicts of interest with respect to the research.

References

[1] Alemi, M., Meghdari, A., Basiri, N. M., & Taheri, A. (2015). The effect of applying humanoid robots as teacher assistants to help Iranian autistic pupils learn English as a foreign language. In Social Robotics: 7th International Conference, ICSR 2015, Paris, France, October 26-30, 2015, proceedings (pp. 1-10). Springer International Publishing. https://doi.org/10.1007/978-3-319-25554-5_1

[2] An, Z. G., Hu, X., & Horn, E. (2018). Chinese inclusive education: The past, present, and future. Intervention in School and Clinic, 54(2), 118-122. https://doi.org/10.1177/1053451218765244

[3] Arunachalam, S., & Luyster, R. J. (2018). Lexical development in young children with autism spectrum disorder (ASD): How ASD may affect intake from the input. Journal of Speech, Language, and Hearing Research, 61(11), 2659-2672. https://doi.org/10.1044/2018_JSLHR-L-RSAUT-18-0024

[4] Baker, D. (2013). Particular polyglots: Multilingual students with autism. Disability & Society, 28(4), 527-541. https://doi.org/10.1080/09687599.2012.717883

[5] Beauchamp, M. L., & MacLeod, A. A. (2017). Bilingualism in children with autism spectrum disorder: Making evidence based recommendations. Canadian Psychology/Psychologie Canadienne, 58(3), 250. https://doi.org/10.1037/cap0000122

[6] Beauchamp, M. L., Rezzonico, S., & MacLeod, A. A. (2020). Bilingualism in school-aged children with ASD: A pilot study. Journal of Autism and Developmental Disorders, 50, 4433-4448. https://doi.org/10.1007/s10803-020-04501-8

[7] Bialystok, E., Craik, F. I., & Luk, G. (2012). Bilingualism: Consequences for mind and brain. Trends in Cognitive Sciences, 16(4), 240-250. https://doi.org/10.1016/j.tics.2012.03.001

[8] Bialystok, E. (2024). Bilingualism modifies cognition through adaptation, not transfer. Trends in Cognitive Sciences, 28(11), 987-997. https://doi.org/10.1016/j.tics.2024.07.012

[9] Bosseler, A., & Massaro, D. W. (2003). Development and evaluation of a computer-animated tutor for vocabulary and language learning in children with autism. Journal of Autism and Developmental Disorders, 33, 653-672. https://doi.org/10.1023/B:JADD.0000006002.82367.4f

[10] Boucher, J. (2012). Research review: structural language in autistic spectrum disorder–characteristics and causes. Journal of Child Psychology and Psychiatry, 53(3), 219-233.https://doi.org/10.1111/j.1469-7610.2011.02508.x

[11] Brown, L., Sherbenou, R. J., & Johnsen, S. K. (2010). TONI-4, test of nonverbal intelligence. Austin, TX: PRO-ED.

[12] Charman, T., Drew, A., Baird, C., & Baird, G. (2003). Measuring early language development in preschool children with autism spectrum disorder using the MacArthur Communicative Development Inventory (Infant Form). Journal of Child Language, 30(1), 213–236. https://doi.org/10.1017/s0305000902005482

[13] Davis, M. H., Di Betta, A. M., Macdonald, M. J., & Gaskell, M. G. (2009). Learning and consolidation of novel spoken words. Journal of Cognitive Neuroscience, 21(4), 803-820. https://doi.org/10.1162/jocn.2009.21059

[14] Davis, T. N., Lancaster, H. S., & Camarata, S. (2016). Expressive and receptive vocabulary learning in children with diverse disability typologies. International Journal of Developmental Disabilities, 62(2),

77-88. https://doi.org/10.1179/2047387715Y.0000000010

[15] Dosi, I., & Sotiriadis, S. (2020). Interventions for early language development in monolingual and bilingual children with autism spectrum disorders: Two case studies. *International Journal of Research* Studies in Education, 9(7), 1-11. https://doi.org/10.5861/ijrse.2020.5047

[16] Drysdale, H., van der Meer, L., & Kagohara, D. (2015). Children with autism spectrum disorder from bilingual families: A systematic review. Review Journal of Autism and Developmental Disorders, 2, 26-38. https://doi.org/10.1007/s40489-014-0032-7

[17] Dumay, N., & Gaskell, M. G. (2007). Sleep-associated changes in the mental representation of spoken words. Psychological Science, 18(1), 35-39. https://doi.org/10.1111/j.1467-9280.2007.01845.x

[18] Ehrler, D. J., & McGhee, R. L. (2008). Primary Test of Nonverbal Intelligence. Austin, TX: PRO-ED.

[19] Ferman, S. (2021). Morpholexical Processes in Children with Autism Spectrum Disorder: Evidence from Artificial Word Learning. Folia Phoniatrica et Logopaedica, 73(3), 248-262.https://doi.org/10.1159/000512849

[20] Franken, T. E., Lewis, C., & Malone, S. A. (2010). Brief report: Are children with autism proficient word learners?. Journal of Autism and Developmental Disorders, 40, 255-259. https://doi.org/10.1007/s10803-009-0847-8

[21] Ge, H., Lee, A. K. L., Yuen, H. K., Liu, F., & Yip, V. (2024). Bilingual exposure might enhance L1 development in Cantonese-English bilingual autistic children: Evidence from the production of focus. Autism, 28(7), 1795-1808. https://doi.org/10.1177/13623613231207449

[22] Gibson, T. A., Oller, D. K., Jarmulowicz, L., & Ethington, C. A. (2012). The receptive–expressive gap in the vocabulary of young second-language learners: Robustness and possible mechanisms. Bilingualism: Language and Cognition, 15(1), 102-116. https://doi.org/10.1017/S1366728910000490

[23] Gladfelter, A., & Goffman, L. (2018). Semantic richness and word learning in children with autism spectrum disorder. Developmental Science, 21(2), e12543. https://doi.org/10.1111/desc.12543

[24] Gonzalez-Barrero, A. M., & Nadig, A. (2017). Verbal fluency in bilingual children with Autism Spectrum Disorders. Linguistic Approaches to Bilingualism, 7(3-4), 460-475.https://doi.org/10.1075/lab.15023.gon

[25] Gonzalez-Barrero, A. M., & Nadig, A. (2018). Bilingual children with autism spectrum disorders: The impact of amount of language exposure on vocabulary and morphological skills at school age. Autism Research, 11(12), 1667-1678. https://doi.org/10.1002/aur.2023

[26] Hambly, C., & Fombonne, E. (2012). The impact of bilingual environments on language development in children with autism spectrum disorders. Journal of Autism and Developmental Disorders, 42, 1342-1352. https://doi.org/10.1007/s10803-011-1365-z

[27] Hambly, C., & Fombonne, E. (2014). Factors influencing bilingual expressive vocabulary size in children with autism spectrum disorders. Research in Autism Spectrum Disorders, 8(9), 1079-1089. https://doi.org/10.1016/j.rasd.2014.05.013

[28] Harper-Hill, K., Copland, D., & Arnott, W. (2014). Efficiency of lexical access in children with autism spectrum disorders: Does modality matter?. Journal of Autism and Developmental Disorders, 44, 1819-1832. https://doi.org/10.1007/s10803-014-2055-4

[29] Hartley, C., & Allen, M. L. (2014). Brief report: Generalisation of word–picture relations in children with autism and typically developing children. Journal of Autism and Developmental Disorders, 44, 2064-2071. https://doi.org/10.1007/s10803-014-2074-1

[30] Hartley, C., Bird, L. A., & Monaghan, P. (2019). Investigating the relationship between fast mapping,

retention, and generalization of words in children with autism spectrum disorder and typical development. Cognition, 187, 126-138. https://doi.org/10.1016/j.cognition.2019.03.001

[31] Hartley, C., Bird, L. A., & Monaghan, P. (2020). Comparing cross-situational word learning, retention, and generalisation in children with autism and typical development. Cognition,200, 104265. https://doi.org/10.1016/j.cognition.2020.104265

[32] Hashim, H. U., Yunus, M. M., & Norman, H. (2022). 'AReal-Vocab': an augmented reality English vocabulary mobile application to cater to mild autism children in response towards sustainable education for children with disabilities. Sustainability, 14(8), 4831.https://doi.org/10.3390/su14084831

[33] Henderson, L., Powell, A., Gareth Gaskell, M., & Norbury, C. (2014). Learning and consolidation of new spoken words in autism spectrum disorder. Developmental Science, 17(6), 858-871.https://doi.org/10.1111/desc.12169

[34] Hu, X., Lee, G. T., Pan, Q., Gilic, L., & Zeng, S. (2023). Effects of foreign mand training on the emergence of foreign tact and listener responses for Chinese-speaking children with autism spectrum disorder. Behavioral Interventions, 38(2), 437-455. https://doi.org/10.1002/bin.1930

[35] Hudry, K., Rumney, L., Pitt, N., Barbaro, J., & Vivanti, G. (2018). Interaction behaviors of bilingual parents with their young children with autism spectrum disorder. Journal of Clinical Child & Adolescent Psychology, 47(sup1), S321-S328. https://doi.org/10.1080/15374416.2017.1286592

[36] Hyter, Y. D. (2007). Pragmatic language assessment: A pragmatics-as-social practice model. Topics in Language Disorders, 27(2), 128-145. https://doi.org/10.1097/01.TLD.0000269929.41751.6b

[37] Jegatheesan, B., Fowler, S., & Miller, P. J. (2010). From symptom recognition to services: How South Asian Muslim immigrant families navigate autism. Disability & Society,25(7), 797-811. https://doi.org/10.1080/09687599.2010.520894

[38] Keller, K., Troesch, L. M., & Grob, A. (2015). A large receptive–expressive gap in bilingual children. Frontiers in psychology, 6, 1284. https://doi.org/10.3389/fpsyg.2015.01284

[39] Kjelgaard, M. M., & Tager-Flusberg, H. (2001). An investigation of language impairment in autism: Implications for genetic subgroups. Language and Cognitive Processes, 16(2-3), 287-308.https://doi.org/10.1080/01690960042000058

[40] Kover, S. T., & Ellis Weismer, S. (2014). Lexical characteristics of expressive vocabulary in toddlers with autism spectrum disorder. Journal of Speech, Language, and Hearing Research, 57(4), 1428-1441. https://doi.org/10.1044/2014_JSLHR-L-13-0006

[41] Larson, C., Rivera-Figueroa, K., Thomas, H. R., Fein, D., Stevens, M. C., & Eigsti, I. M. (2022). Structural language impairment in Autism Spectrum Disorder versus Loss of Autism Diagnosis: Behavioral and neural characteristics. NeuroImage: Clinical, 34, 103043. https://doi.org/10.1016/j.nicl.2022.103043

[42] Li, M., Lin, Y., Bao, T., Zhao, Q., Wang, Y., Li, M., ... & Zhu, D. (2022). Inclusive education of elementary students with autism spectrum disorders in Shanghai, China: From the teachers' perspective. BioScience Trends, 16(2), 142-150. https://doi.org/10.5582/bst.2022.01104

[43] Lord, C., Rutter, M., DiLavore, P.C., Risi, S., Gotham, K., & Bishop, S.L. (2012). Autism Diagnostic Observation Schedule, Second Edition: ADOS-2. Torrance, CA: Western Psychological Services.

[44] Luyster, R., & Lord, C. (2009). Word learning in children with autism spectrum disorders. Developmental psychology, 45(6), 1774-1786. https://doi.org/10.1037/a0016223

[45] Mathée-Scott, J., Larson, C., Venker, C., Pomper, R., Edwards, J., Saffran, J., & Ellis Weismer, S. (2021). Use of mutual exclusivity and its relationship to language ability in toddlers with autism spectrum

disorder. Journal of Autism and Developmental Disorders, 1-12. https://doi.org/10.1007/s10803-021-05321-0

[46] McGregor, K. K., Berns, A. J., Owen, A. J., Michels, S. A., Duff, D., Bahnsen, A. J., & Lloyd, M. (2012). Associations between syntax and the lexicon among children with or without ASD and language impairment. Journal of Autism and Developmental Disorders, 42, 35-47. https://doi.org/10.1007/s10803-011-1210-4

[47] Murdaugh, D. L., Maximo, J. O., & Kana, R. K. (2015). Changes in intrinsic connectivity of the brain's reading network following intervention in children with autism. Human Brain Mapping, 36(8), 2965-2979. https://doi.org/10.1002/hbm.22821

[48] Norbury, C. F., Griffiths, H., & Nation, K. (2010). Sound before meaning: Word learning in autistic disorders. Neuropsychologia, 48(14), 4012-4019. https://doi.org/10.1016/j.neuropsychologia.2010.10.015

[49] Oller, D. K., Pearson, B. Z., & Cobo-Lewis, A. B. (2007). Profile effects in early bilingual language and literacy. Applied Psycholinguistics, 28(2), 191-230. https://doi.org/10.1017/S0142716407070117

[50] Padmadewi, N. N., & Artini, L. P. (2017). Teaching English to a student with autism spectrum disorder in regular classroom in Indonesia. International Journal of Instruction, 10(3), 159-176. https://doi.org/10.12973/iji.2017.10311a

[51] Patael, S., & Diesendruck, G. (2008). Intentions help children learn meaningful rules. Journal of Child Language, 35(1), 221-234. https://doi.org/10.1017/S0305000907008331

[52] Peristeri, E., Baldimtsi, E., Andreou, M., & Tsimpli, I. M. (2020). The impact of bilingualism on the narrative ability and the executive functions of children with autism spectrum disorders. Journal of Communication Disorders, 85, 105999. https://doi.org/10.1016/j.jcomdis.2020.105999

[53] Perovic, A., Modyanova, N., & Wexler, K. (2013). Comprehension of reflexive and personal pronouns in children with autism: A syntactic or pragmatic deficit?. Applied Psycholinguistics, 34(4), 813-835. https://doi.org/10.1017/S0142716412000033

[54] Peristeri, E., Vogelzang, M., Tsimpli, I. M., & Durrleman, S. (2024). Bilingualism and second-order theory of mind development in autistic children over time: Longitudinal relations with language, executive functions, and intelligence. Autism Research: Official Journal of the International Society for Autism Research, 17(9), 1818–1829. https://doi.org/10.1002/aur.3214

[55] Petersen, J. M., Marinova-Todd, S. H., & Mirenda, P. (2012). Brief report: An exploratory study of lexical skills in bilingual children with autism spectrum disorder. Journal of Autism and Developmental Disorders, 42, 1499-1503. https://doi.org/10.1007/s10803-011-1366-y

[56] Rescorla, L., & Safyer, P. (2013). Lexical composition in children with autism spectrum disorder (ASD). Journal of Child Language, 40(1), 47-68. https://doi.org/10.1017/S0305000912000232

[57] Rothwell, C., Westermann, G., & Hartley, C. (2024). How do autistic and neurotypical children's interests influence their accuracy during novel word learning?. Journal of Autism and Developmental Disorders, 54(9), 3301-3315. https://doi.org/10.1007/s10803-023-06066-8

[58] Skewes, J. C., Kemp, T., Paton, B., & Hohwy, J. (2020). How are attention, learning, and social cognition related on the non-clinical autistic spectrum?. Acta Psychologica, 210, 103157. https://doi.org/10.1016/j.actpsy.2020.103157

[59] Sukenik, N., & Tuller, L. (2023). Lexical semantic knowledge of children with ASD—A review study. Review Journal of Autism and Developmental Disorders, 10(1), 130-143. https://doi.org/10.1007/s40489-021-00272-9

[60] Tager-Flusberg, H. (2015). Defining language impairments in a subgroup of children with autism spectrum disorder. Science China Life Sciences, 58, 1044-1052. https://doi.org/10.1007/s11427-012-4297-8

[61] Tager-Flusberg, H., & Caronna, E. (2007). Language disorders: autism and other pervasive developmental disorders. Pediatric Clinics of North America, 54(3), 469-481. https://doi.org/10.1016/j.pcl.2007.02.011

[62] Tenenbaum, E. J., Amso, D., Abar, B., & Sheinkopf, S. J. (2014). Attention and word learning in autistic, language delayed and typically developing children. Frontiers in Psychology, 5, 490. https://doi.org/10.3389/fpsyg.2014.00490

[63] Wittke, K., Mastergeorge, A. M., Ozonoff, S., Rogers, S. J., & Naigles, L. R. (2017). Grammatical language impairment in autism spectrum disorder: Exploring language phenotypes beyond standardized testing. Frontiers in Psychology, 8, 532. https://doi.org/10.3389/fpsyg.2017.00532

[64] Yu, B. (2013). Issues in bilingualism and heritage language maintenance: Perspectives of minority-language mothers of children with autism spectrum disorders. American Journal of Speech-Language Pathology, 22, 10-24. https://doi.org/10.1044/1058-0360(2012/10-0078)

[65] Zhou, H., Xu, X., Yan, W. et al. (2020). Prevalence of autism spectrum disorder in China: A nationwide multi-center population-based study among children aged 6 to 12 years. Neuroscience Bulletin, 36(8), 961–971. https://doi.org/10.1007/s12264-020-00530-6

[66] Zohoorian, Z., Zeraatpishe, M., & Matin Sadr, N. (2021). Effectiveness of the picture exchange communication system in teaching English vocabulary in children with autism spectrum disorders: A single-subject study. Cogent Education, 8(1), 1892995. https://doi.org/10.1080/2331186X.2021.1892995

[67] Zwart, F. S., Vissers, C. T. W., van der Meij, R., Kessels, R. P., & Maes, J. H. (2017). Autism: Too eager to learn? Event related potential findings of increased dependency on intentional learning in a serial reaction time task. Autism Research, 10(9), 1533-1543. https://doi.org/10.1002/aur.1802