The Impact of Attention and Memory on Delayed Vocabulary Development in Children with Autism

Authors: Hou Wenwen, Su Yi, Su Yi

Date: 2022-06-06T00:00:00+00:00

Abstract

One manifestation of language impairment in autism is delayed vocabulary development, which may be associated with attention and memory deficits. Current research findings indicate that children with autism have difficulty utilizing effective information provided by social attention during vocabulary learning, and their attention is readily disrupted by irrelevant stimuli. This may result in unstable object-word associations, thereby affecting the further integration of these associations into the mental lexicon and their retention in memory. Future research should investigate the developmental trajectory and mechanisms through which joint attention influences vocabulary learning in children with autism, examine how children' s vocabulary knowledge affects their vocabulary memory, and attend to vocabulary learning processes and individual differences among children with autism in naturalistic contexts.

Full Text

The Influence of Attention and Memory on Vocabulary Development Delays in Children with Autism Spectrum Disorder

HOU Wenwen[1], SU Yi (ESTHER)[1]
[1]Child Language Lab, School of Foreign Languages, Central South University, Changsha 410083, China

Abstract: Vocabulary development delay is one manifestation of language impairment in autism spectrum disorder (ASD), which may be related to deficits in attention and memory. Current research findings indicate that children with ASD have difficulty utilizing effective information provided by social attention when learning vocabulary, and their attention is easily distracted by irrelevant

stimuli. This may lead to unstable object-word associations, affecting their ability to further integrate these associations into their mental lexicon and store them in memory. Future research should investigate the developmental trajectory and mechanisms through which joint attention influences vocabulary learning in children with ASD, the impact of children' s lexical knowledge on their vocabulary memory, and examine the vocabulary learning process and individual differences in children with ASD in naturalistic settings.

Keywords: vocabulary development, word learning, attention, memory, autism spectrum disorder
Classification: B844

1. Introduction

Autism Spectrum Disorder (ASD) is a group of neurodevelopmental disorders characterized by core features of social and communication difficulties, repetitive behaviors, and restricted interests (American Psychiatric Association, 2013). Although language impairment is not included in the latest diagnostic criteria for autism, delays and abnormalities in receptive and expressive language development are very common in individuals with ASD (Kover & Ellis Weismer, 2014; Reinhartsen et al., 2019), and language impairment greatly affects the quality of life and developmental outcomes for individuals with ASD (Bruyneel et al., 2019).

Vocabulary acquisition is a crucial aspect of children' s language development. Numerous studies have found that preschool children with ASD exhibit delayed vocabulary development compared to typically developing children (Ellis Weismer et al., 2010; Luyster et al., 2007), with approximately 30% of minimally verbal individuals with ASD failing to develop speech or only producing minimal words or phrases throughout their lives (Bal et al., 2016). Grandgeorge et al. (2009) investigated early language development in 162 children with ASD, finding that 87 (53.7%) produced their first word after 24 months, and 114 (70.3%) did not produce their first phrase until after 33 months.

Charman et al. (2003) used the MacArthur-Bates Communicative Development Inventory (Infant Form) to measure language development in 134 children with ASD ranging in age from 1 year 6 months to 7 years 4 months. The results showed that children with ASD lagged behind typically developing children in both vocabulary comprehension and expression levels. In terms of vocabulary comprehension, children with ASD could not understand more than 100 words until after age 2, whereas 50% of typically developing children could understand over 100 words by 16 months. Regarding vocabulary production, children with ASD could only produce more than 30 words between ages 2-3, while 50% of typically developing children could produce over 30 words by 16 months.

Su et al. (2018) used the Chinese Communicative Development Inventory to

assess vocabulary development in 160 Chinese-speaking children with ASD aged 17-83 months, finding that their vocabulary level lagged approximately 30 months behind typically developing children, and 59.38% of Chinese-speaking children with ASD could produce only minimal vocabulary. These studies demonstrate that most children with ASD experience vocabulary development delays, which significantly impacts their overall language development and other cognitive abilities. Therefore, investigating vocabulary learning and its underlying mechanisms in children with ASD not only helps us understand the deeper mechanisms of language acquisition but also provides crucial guidance for implementing precise early language interventions.

Currently, we know little about the mechanisms underlying vocabulary development delays in children with ASD. Although some studies have found that children with ASD can utilize cognitive constraints such as the principle of mutual exclusivity (Mathée-Scott et al., 2021) and cross-situational statistical learning (Hartley et al., 2020) to establish connections between objects and words, their vocabulary development remains delayed. This suggests that cognitive constraint principles may be intact in ASD, while more general cognitive systems related to word learning are impaired (Arunachalam & Luyster, 2018; Venker et al., 2018).

Word learning is a complex process that requires children to establish connections between objects they see and word labels they hear (fast mapping), while also consolidating these connections and storing them in long-term memory (Spiegel & Halberda, 2011). Attention plays a crucial role in the fast mapping stage of word learning by reducing referential uncertainty in the environment and helping children establish connections between word labels and referents (Fitch et al., 2020; Venker et al., 2018). Once children form object-word associations, they must store them in memory for later retrieval. Both episodic and semantic memory are involved in the acquisition and consolidation of new words (Davis & Gaskell, 2009; Takashima et al., 2017). Clearly, word learning relies on the participation of both attention and memory mechanisms. However, attention patterns and memory functions are both atypical in children with ASD to some degree (Bhat et al., 2010; Boucher et al., 2012; Johnels et al., 2014; Jones & Klin, 2013; Nyström et al., 2019). Children with ASD show reduced attention to social stimuli (Chawarska et al., 2013; Jones & Klin, 2013) and deficits in joint attention (Nyström et al., 2019) even before language emerges, causing them to miss numerous word learning opportunities. Deficits in episodic and semantic memory also affect vocabulary consolidation in children with ASD (Boucher et al., 2012). Therefore, this paper will review recent literature on word learning in children with ASD from the perspectives of attention and memory, analyze how attention and memory mechanisms affect their word learning, and propose directions for future research.

2.1 The Influence of Social Attention on Word Learning in Children with ASD

Social interaction provides an important context for language acquisition, offering rich social information and language learning opportunities (Tenenbaum et al., 2014). Other people' s faces, particularly the eyes and mouth, provide important cues for children' s word learning (Gangopadhyay & Kaushanskaya, 2020; Tsang et al., 2018). However, infants at high risk for ASD show reduced attention to social scenes as early as 6 months (Chawarska et al., 2013), and their attention to eyes gradually declines between 2-6 months (Jones & Klin, 2013). Additionally, high-risk infants with ASD exhibit joint attention deficits by 10 months (Nyström et al., 2019). Atypical social attention causes children with ASD to miss numerous word learning opportunities, thereby hindering their vocabulary and language development (Haebig et al., 2021; Jiménez et al., 2021).

Children' s selective attention to faces changes dynamically across vocabulary development stages. Specifically, attention to a speaker' s mouth during early vocabulary learning facilitates vocabulary production. Research shows that typically developing infants attend more to a speaker' s mouth than eyes at 8-10 months, decrease mouth attention at 12 months (Lewkowicz & Hansen-Tift, 2012), and refocus on the mouth at 14-18 months (Hillairet de Boisferon et al., 2018). This is because infants begin babbling at 8-10 months, and attending to others' mouths provides audiovisual cues that help them acquire native language phonological representations and articulatory actions (Hillairet de Boisferon et al., 2018; Lewkowicz & Hansen-Tift, 2012). By 12 months, infants have become familiar with native phonological representations and thus reduce attention to speakers' mouths. However, starting at 14 months, as infants' vocabulary learning accelerates, they refocus on speakers' mouths to utilize audiovisual cues for word learning (Hillairet de Boisferon et al., 2018; Lewkowicz & Hansen-Tift, 2012).

Research indicates that increased attention to speakers' mouths in children with ASD predicts expressive language development (Campbell et al., 2014; Young et al., 2009). Habayeb et al. (2021) investigated the relationship between attention patterns while watching others speak and expressive language abilities in typically developing children and children with ASD aged 10-25 months. The results showed that although both groups attended more to speakers' mouths than eyes, mouth attention was positively correlated with expressive language abilities in typically developing children and verbally fluent children with ASD, but not in minimally verbal children with ASD who had delayed vocabulary development. Tenenbaum et al. (2017) also found that placing target objects to be named near the speaker' s mouth significantly increased attention to both target objects and the speaker' s mouth in children with ASD who could already produce words, thereby facilitating new word learning. Habayeb et al. (2021) proposed that minimally verbal children with ASD who have delayed language development, despite also showing increased mouth attention, may acquire words through

different mechanisms than typically developing children and verbally fluent children with ASD. While typically developing children and verbally fluent children with ASD learn words through redundant information generated during audiovisual synchrony, minimally verbal children with ASD may merely attend to the physical aspects of visual and auditory stimuli, neglecting the socio-adaptive value of this synchrony. Future research should further examine individual differences in word learning among children with ASD.

When children begin producing phrases and more complex sentences around age 2, they decrease attention to speakers' mouths and focus more on speakers' eyes (Habayeb et al., 2021). During speech, speakers' eyes may shift toward corresponding objects, guiding children to redirect attention to target objects and connect them with heard words. This process is called joint attention—behavior where two individuals share attention on an object or event (Bruner, 1974). Joint attention is a crucial foundation for early word learning and language development (Adamson et al., 2017; Tomasello & Farrar, 1986). However, current research has not yielded consistent findings regarding whether children with ASD can utilize joint attention to learn words.

Some studies have found that children with ASD can also use cues provided by others' gaze shifts to learn words (Bean Ellawadi & McGregor, 2016; Field et al., 2019; McGregor et al., 2013). These studies demonstrated that children with ASD can follow others' gaze to redirect attention to target objects, thereby mapping words onto objects. However, other studies have found that even when gaze-following abilities are intact, children with ASD still struggle to successfully acquire words if they lack sustained attention to targets (Akechi et al., 2011; Gliga et al., 2012). For instance, Gliga et al. (2012) found that 3-year-old children with ASD who had poor social skills could follow others' gaze but failed to map words onto objects.

In addition to gaze shifting, joint attention is often accompanied by pointing, which is therefore considered a form of nonverbal joint attention (Paparella et al., 2011). Field et al. (2019) examined whether children with ASD (mean age 9 years) could use social cues such as gaze shifting and pointing to learn words. The experimental task included four cue types: eye gaze, referential pointing, incidental pointing, and a combination of gaze and referential pointing. Field et al. found that children with ASD could use all four cues to map words onto objects. Notably, the ability of children with ASD to learn words using gaze shifting cues was positively correlated with age. Field et al. suggested this might be because joint attention abilities improve through intervention as children with ASD grow older, thereby enhancing word learning performance.

Furthermore, Field et al. found that both typically developing children and children with ASD could successfully map words onto objects even under "incidental pointing" conditions. This may be because in Field et al.' s study, "incidental pointing" involved the demonstrator pointing to an object while looking in the opposite direction. Despite the conflict between eye and hand cues, children still interpreted the pointing gesture as intentional, enabling word mapping. Be-

cause Field et al. used older children with ASD (mean age 9 years) and their manipulation of "incidental pointing" could not verify whether children with ASD could distinguish referential from non-referential intent, Maes et al. (2021) further investigated responses to referential versus incidental pointing in 3-5-year-old children with ASD using a word learning paradigm. They found that typically developing children could quickly map objects to words only under referential pointing conditions, whereas children with ASD rarely shifted attention to the pointing location under either condition. This indicates that children with ASD have difficulty distinguishing referential from incidental pointing and cannot understand the referential intent conveyed by pointing.

These results demonstrate that although social cues such as gaze following and pointing play important roles in word learning, they are not determining factors. Sustained attention to and processing of target objects are critical for word learning in children with ASD. This also reflects that social indexical cues like eyes do not participate in children' s word learning as general spatial cues but rather convey the referential intent of the joint attention initiator. Children must understand the intentional information contained in eye gaze and increase attention to target objects to acquire new words (Çetinçelik et al., 2021; Yu et al., 2019). In studies where children with ASD could use eye cues for fast mapping, they may have treated eye cues as spatial markers and matched novel objects to word labels through associative learning (Bean Ellawadi & McGregor, 2016; McGregor et al., 2013).

Furthermore, word learning is a process requiring audiovisual integration, which demands not only that children can respond to others' joint attention but also that they shift attention to heard objects at the appropriate time (Venker et al., 2018). Although children with ASD possess gaze-following abilities, they struggle to establish correct object-word connections if they cannot follow others' gaze at the right moment. Liu et al. (2021) investigated the temporal synchrony of children with ASD' s responses to joint attention and found that their synchrony was lower than that of typically developing children and required more time. This may prevent children with ASD from shifting attention to objects corresponding to novel words at the appropriate time during word learning, resulting in failure to establish correct word-object connections.

The aforementioned studies indicate that although children with ASD can selectively attend to speakers' faces during word learning like typically developing children, increasing attention to speakers' mouths in early vocabulary learning stages and following others' gaze, they have difficulty utilizing redundant information provided by audiovisual synchrony and sustaining attention to target objects in joint attention. They also cannot shift attention to heard target objects at appropriate times, all of which hinder the establishment of word-object connections in children with ASD.

2.2 The Influence of Domain-General Visual Attention on Word Learning in Children with ASD

In addition to social attention, domain-general attention in children with ASD also affects their word learning. Visual attention in children with ASD is influenced by object salience; compared to typically developing children, they show greater preference for geometric patterns and novel, brightly colored objects (Bacon et al., 2020; Wang et al., 2015). Moreover, children with ASD have difficulty disengaging attention from objects, manifesting as attention disengagement deficits (Baranek et al., 2018; Kleberg et al., 2017). These atypical attention patterns impede word learning and language development in children with ASD at various levels (Arunachalam & Luyster, 2018; Venker et al., 2018).

The preference for brightly colored objects in children with ASD affects their word recognition and learning. In a word recognition task, Venker et al. (2021) found that the higher the salience of distractor images unrelated to the target word, the more significantly attention to target word images decreased in 2-3-year-old children with ASD. This indicates that attention to important lexical information in children with ASD is vulnerable to interference from highly salient irrelevant stimuli. Carter and Hartley (2021) found that using color photographs as word learning materials, compared to black-and-white images, resulted in better learning accuracy and retention duration for new words in children with ASD. Notably, when learning materials were color photographs, children with ASD showed even higher accuracy in recalling novel words than typically developing children (Carter & Hartley, 2021). Carter and Hartley (2021) proposed that children with ASD' s superior memory for new words in the color photograph condition occurred because color images are more concrete than black-and-white images, and children with ASD have advantages in visual processing of object features over typically developing children. This visual processing advantage strengthens the word-object connections formed by children with ASD, leading to better memory (Carter & Hartley, 2021). However, it may also be because color photographs have stronger visual salience than black-and-white images, better capturing the attention of children with ASD, thus resulting in better word memory in the color photograph condition. Future research needs to further verify the effects of object salience and visual processing on word learning in children with ASD.

Furthermore, children with ASD' s attention to object color, novelty, and other features also affects their vocabulary expansion and category learning. Shape bias is an important strategy for children to expand vocabulary and learn categories, referring to the tendency to match novel word labels to object shape rather than color or texture (Landau et al., 1988). Typically developing children show shape bias around age two, but many studies have found that children with ASD do not exhibit this tendency (Abdelaziz et al., 2018; Tecoulesco et al., 2021). Some researchers have found that the lack of shape bias in children with ASD may be related to their excessive attention to more salient features such as object color and novelty (Tovar et al., 2020). Tovar et al. (2020) argued

that previous research on shape bias in children with ASD used novel objects, neglecting the common characteristic of these novel objects—namely, the effect of novelty itself on task performance in children with ASD. Tovar et al. (2020) found that 8-year-old children with ASD did not show shape bias in object categorization tasks and, compared to typically developing children, were more likely to associate object color and novelty with new words. These results reflect that attention deficits to important object attributes and excessive attention to object novelty may jointly contribute to atypical shape bias in children with ASD.

Attention disengagement difficulties in children with ASD also adversely affect their word learning. Children' s language environments are filled with auditory signals and visual information, and to successfully learn language, children must shift attention to relevant people, objects, or events at appropriate times (Venker, 2017). This requires flexible attention shifting across different objects and events, and attention disengagement deficits may lead to imbalances between auditory and visual information, negatively impacting word learning and language development. Venker (2017) found that 4-7-year-old children with ASD who had attention disengagement difficulties processed familiar words more slowly and with lower accuracy. Slow word processing speed affects subsequent language development (Marchman et al., 2016). A recent study also found that infants' attention disengagement ability at 4 months predicted their sound signal discrimination ability at 7 months (Russo et al., 2021). Better attention disengagement at 4 months was associated with easier sound signal discrimination at 7 months. These results demonstrate that children' s attention to different objects and events in space simultaneously regulates their temporal attention to different auditory signals, and that children' s word learning and language processing depend on coordination between visual and auditory information across time and space (Russo et al., 2021). Attention disengagement difficulties in children with ASD may exacerbate their word learning difficulties and even affect subsequent language comprehension and processing.

In summary, children with ASD may treat social attention cues as general attention cues to reduce referential ambiguity and enable fast mapping. Domain-general attention abnormalities not only prevent children with ASD from matching objects to novel word labels at appropriate times but also cause them to shift attention to irrelevant objects, resulting in unstable word-object connections.

---

3. Vocabulary Consolidation and Memory in Children with ASD

Word learning is a long-term task. Retention and memory of newly learned words are crucial components of word learning. Fast mapping alone is insufficient for children' s word learning; children must store new words in memory and integrate them into their mental lexicon for later retrieval.

Current research findings present some controversy regarding whether word retention and memory are intact in children with ASD. This may be related to differences in recall intervals used across studies. Studies finding that children with ASD can retain newly learned words after acquisition have employed immediate retention paradigms, testing whether children can match word labels to target objects 5 minutes after word learning (Gliga et al., 2021; Hartley et al., 2019, 2020; Venker, 2019). For example, Hartley et al. (2020) investigated cross-situational word learning abilities in children with ASD with varying cognitive abilities (mean age 8.7 years) and found that after 5 minutes, children with ASD could still match novel word labels to target objects. Based on these immediate recall tasks, the ability of children with ASD to retain new words appears intact.

However, studies requiring children to recall novel words after longer intervals have found that children with ASD have poorer memory for new words compared to typically developing children. For example, Norbury et al. (2010) found that in immediate recall tasks after learning new words, 8-year-old children with ASD even outperformed age-matched typically developing children. However, when recalled after 4 weeks, typically developing children showed memory for the new words in both semantic and phonological tests, whereas children with ASD performed poorly. This suggests that typically developing children need time to integrate new words into their mental lexicon after learning, while children with ASD, despite good performance on immediate recall tasks, fail to integrate new words with existing vocabulary over the long term. The good performance of children with ASD on immediate retention tasks may merely reflect their phonological processing advantages (Hudac et al., 2018; Kujala et al., 2007). The heightened sensitivity to phonology in children with ASD may facilitate immediate phonological retention of newly learned words, but integrating newly learned words into the mental lexicon requires participation of additional cognitive components.

During the integration of new words into the mental lexicon, both episodic and semantic memory participate in word acquisition and consolidation (Takashima et al., 2017). According to the dual memory systems model of word learning, the first stage of word consolidation is rapid word familiarization, where new words are represented as distinct personal experiences in the medial temporal lobe and hippocampus. The second stage is slow lexical consolidation, where word representations are extracted from episodic memory to form more systematic and stable lexical representations in the neocortex, which are then integrated into semantic memory (Davis & Gaskell, 2009; Takashima et al., 2017). Sleep plays an indispensable role in transforming episodic representations of individual word learning experiences in episodic memory into lexical representations in the neocortex. Research shows that napping can strengthen children' s memory for newly learned words (Axelsson et al., 2016; He et al., 2020), and sleep problems may contribute to word memory difficulties in children with ASD (Botting & Baraka, 2017).

Fletcher et al. (2020) used polysomnography to examine changes in word consolidation and memory before and after sleep in 8-12-year-old children with ASD. Fletcher et al. (2020) first had children with ASD learn nine rare animal names, then tested their memory for the new words before sleep, the morning after waking, and one month later through definition, naming, and rapid semantic decision tasks. The results showed no significant differences between children with ASD and typically developing children on all word tasks on the learning day and the following day. However, after one month, children with ASD showed significantly greater forgetting of newly learned animal names than typically developing children. Additionally, Fletcher et al. found that children with ASD had lower sigma power and sleep spindle activity levels during non-rapid eye movement sleep. Sleep spindles could predict memory for newly learned animal names in typically developing children but not for familiar animal names, indicating that sleep plays a specific role in consolidating new semantic knowledge. However, for children with ASD, sleep spindles consolidated both new and familiar animal words. These differences suggest that sleep spindles specifically consolidate newly learned semantic knowledge in typically developing children but consolidate semantic knowledge generally in children with ASD, strengthening both new and existing knowledge during sleep (Fletcher et al., 2020). Consequently, children with ASD may show memory for new words immediately after learning, but because these words are not adequately integrated, their forgetting rate for new words becomes faster after some time.

Furthermore, an important marker of word integration is the emergence of lexical competition effects. During word integration, children and adults experience competition between phonologically similar words (Weighall et al., 2017). Henderson et al. (2014) investigated the time course of integrating new words into existing lexical knowledge in 8-13-year-old children with ASD. They found that typically developing children did not show lexical competition effects on the day of word learning but exhibited them on the following day, consistent with most previous research showing that lexical competition effects occur after sleep (Gaskell & Dumay, 2003; Walker et al., 2019) and with the dual memory systems model of word learning. According to this model, to avoid interference from new information on existing knowledge, new information must be integrated slowly into existing knowledge (Davis & Gaskell, 2009). However, children with ASD showed lexical competition effects on the day of word learning, which weakened on the following day. In terms of word recall, both children with ASD and typically developing children showed accurate recall of new words on the day of learning and the following day (Henderson et al., 2014). This suggests that explicit memory for new words may be intact in children with ASD, but they have deficits in word integration.

Overall, children with ASD show deficits in word consolidation and memory. However, it remains unclear whether these difficulties in children with ASD are related to sleep problems or to issues existing prior to the word consolidation stage. For example, research has found that when object-word connections formed before consolidation are weak, sleep cannot consolidate and integrate

new words (Walker et al., 2019). Vlach and DeBrock (2019) also found that typically developing preschoolers using only cross-situational statistical learning (identifying statistical regularities in word label and object co-occurrence frequencies) for word-object mapping had difficulty maintaining formed word-object connections in long-term memory. Vlach and DeBrock (2019) suggested this might be because word-object connections established through repeated co-occurrence frequencies are not stable enough, the salience of these novel objects is insufficient, and without support from social indexical cues such as joint attention, children quickly forget new words. Therefore, in addition to sleep problems, it is also possible that because attention in children with ASD is easily distracted by highly salient irrelevant stimuli and they have difficulty using referential intent in social attention to strengthen connections between objects and new words, the object-new word connections formed during the fast mapping stage are not stable enough to be consolidated and integrated through sleep. Future research needs to further test this hypothesis.

---

4. Summary and Outlook

Based on current research, vocabulary development delays in children with ASD may stem from impairments in more general attention and memory functions. Children with ASD are more likely to attend to highly salient but word-learning-irrelevant objects and consolidate familiar words more during sleep, both of which impede their word learning and language development. These results suggest that vocabulary development delays in children with ASD may not be merely a matter of timing but reflect qualitative differences from typically developing children in the word learning process. Although attention and memory participate as domain-general cognitive mechanisms in typically developing children' s word learning, they also have specific aspects. Typically developing children strengthen object-word label connections by recognizing referential intent in social attention (Çetinçelik et al., 2021), and during subsequent sleep, sleep spindles further consolidate newly learned words, forming more systematic and stable lexical representations in the neocortex and integrating them into existing lexical knowledge (Axelsson et al., 2016). Children with ASD may treat social attention cues only as general spatial cues to reduce referential uncertainty, but because their attention is easily distracted by highly salient irrelevant stimuli (Venker et al., 2021), the object-word label connections they form are not stable enough. Additionally, they do not receive specific consolidation of new knowledge from sleep spindles during sleep, making it difficult to form stable and systematic lexical representations in the neocortex (Fletcher et al., 2020). Consequently, children with ASD are more likely to forget new words after extended periods compared to typically developing children. Word learning is a continuum from word-object connections to word consolidation and memory, yet most current research on word learning in children with ASD focuses only on examining their ability to use various cognitive strategies for fast

mapping. Few studies have simultaneously investigated the effects of attention and memory on their word learning and the relationship between attention and memory in word learning. We look forward to future research that combines attention and memory to examine the word learning process and the causes of developmental delays in children with ASD, thereby deepening our understanding of the mechanisms underlying vocabulary development delays in this population.

First, future research needs to further investigate the mechanisms and developmental trajectory of how joint attention influences vocabulary development. Some researchers propose that joint attention plays an important mediating role between motor abilities and language development (Bruyneel et al., 2019; Edmunds et al., 2017). The emergence of new motor skills changes how children interact with people and objects in their environment, which can promote subsequent communication and language development. Motor development is often accompanied by joint attention; when children begin sitting and grasping, they pick up objects to show or give to caregivers, who may then name the objects, providing opportunities for word learning (Choi et al., 2018). Bruyneel et al. (2019) found that motor skills at 10 months in high-risk infants with ASD and typically developing infants influenced their expressive and receptive language at 36 months, mediated by their joint attention abilities at 14 months. However, early motor skills such as sitting and walking are related to joint attention behaviors in high-risk and low-risk infants with ASD but not to joint attention behaviors in 3-5-year-old children with ASD (Franchini et al., 2018). This suggests that joint attention may mediate the relationship between motor skills and language development in early childhood, but when motor development matures, joint attention no longer influences language development or influences it through other means. Therefore, future longitudinal tracking studies are needed to investigate the trajectory of joint attention' s influence on vocabulary development in children with ASD, identifying critical time points and influencing factors, such as when joint attention' s impact on vocabulary development peaks and when it declines. This is crucial for promoting vocabulary development and developing appropriate interventions for children with ASD.

Second, research indicates that individuals' existing lexical knowledge also influences the consolidation and integration of new words. The richer an individual' s lexical knowledge, the stronger the lexical competition effect and the better the integration outcome—a phenomenon known as the "Matthew effect" (James et al., 2017; Stanovich, 1986). However, no studies have directly examined how lexical knowledge in children with ASD affects their word integration, leaving it unknown whether differences in lexical knowledge among children with ASD influence their word consolidation. Future research needs to investigate the relationships between sleep, lexical knowledge, and word consolidation in children with ASD to clarify the mechanisms underlying their word consolidation and memory difficulties. Additionally, current research on word consolidation and memory in children with ASD has focused primarily on school-age children' s

word memory, and it remains unclear how preschool children with ASD store words in long-term memory. Future studies should also investigate early word consolidation and memory in children with ASD.

Third, there are substantial individual differences in word learning among children with ASD. Vocabulary development levels in children with ASD may be related to individual nonverbal cognitive abilities and current language expression abilities. Children with ASD with different cognitive abilities show different difficulties in the word learning process. For example, Joseph et al. (2019) investigated word learning abilities in 29 minimally verbal children and adolescents with ASD aged 5-17 years. The results showed that among the 29 participants, 14 could neither use the mutual exclusivity constraint principle to learn new words nor retain words in memory. Eight could use the mutual exclusivity constraint principle to learn words but could not retain them, while seven could both learn new words and maintain them in the short term. The inability to use the mutual exclusivity constraint principle was related to nonverbal cognitive abilities, whereas word retention difficulties were related to expressive language abilities in children and adolescents with ASD. This indicates that there are substantial individual differences in word learning among individuals with ASD, affecting different stages of word learning. Future research should select children with ASD with different language/cognitive abilities to investigate how their attention patterns and memory affect different stages of word learning, thereby providing targeted intervention methods for individuals with different cognitive abilities.

Moreover, most current research on word learning in children with ASD has been conducted in laboratory settings. However, can the learning mechanisms revealed in laboratory settings reflect children' s word learning processes in real-world contexts? That is, do children actually use these mechanisms or strategies during natural word learning? These questions warrant further investigation. For example, many studies have used the fast mapping experimental paradigm to measure children' s word learning abilities. However, some researchers have proposed that fast mapping may be more of an experimental task than a learning mechanism (Gernsbacher & Morson, 2019). Additionally, current laboratory research primarily presents children with ASD with unfamiliar objects and then names them, examining whether children can match novel word labels to target objects. These experimental tasks largely neglect children' s agency in word learning and focus only on children with ASD's ability to use cues to learn words themselves, with little exploration of the role parents play in their word learning. However, word learning in natural contexts is an active process where children create numerous word learning opportunities by exploring their environment and manipulating interesting objects (Yu & Smith, 2012). In this process, children are active information seekers while caregivers serve as information providers, and the combination of children' s behaviors and caregivers' responses jointly promotes children's word learning (Chen et al., 2021; Suarez-Rivera et al., 2019). Future research should focus more on the word learning process of children with ASD in naturalistic settings, examining how children' s own attention

and environmental exploration, along with parental responsiveness and support, jointly influence word learning in real parent-child interactions. This will help us better understand the difficulties children with ASD encounter during natural word learning and assist us in finding more effective and targeted intervention methods.

Finally, whether the attention and memory mechanisms related to word learning in children with ASD are specific to word learning or show similar patterns in other domain learning (e.g., grammar acquisition) is also a question worth exploring in future research. This will help us further clarify whether attention and memory are indeed the underlying mechanisms of vocabulary development delays in children with ASD. Meanwhile, beyond attention and memory mechanisms, whether children with ASD can follow the vocabulary development trajectory and learning process of typically developing children, adhering to lexical rules (e.g., noun bias, shape bias) or cognitive constraint principles (e.g., mutual exclusivity, holistic learning, cross-situational statistical learning) to acquire words is also an important topic worthy of investigation. This will facilitate deeper understanding of universal mechanisms in human word learning and identify atypical characteristics in word learning among children with ASD.

References

Abdelaziz, A., Kover, S. T., Wagner, M., & Naigles, L. R. (2018). The shape bias in children with autism spectrum disorder: Potential sources of individual differences. Journal of Speech, Language, and Hearing Research, 61(11), 2685-2702. https://doi.org/10.1044/2018_{jslhr}-l-rsaut-18-0027

Adamson, L. B., Bakeman, R., Suma, K., & Robins, D. L. (2017). An expanded view of joint attention: Skill, engagement, and language in typical development and autism. Child Development, 90(1), e1–e18. https://doi.org/10.1111/cdev.12973

Akechi, H., Senju, A., Kikuchi, Y., Tojo, Y., Osanai, H., & Hasegawa, T. (2011). Do children with ASD use referential gaze to learn the name of an object? An eye-tracking study. Research in Autism Spectrum Disorders, 5(3), 1230–1242. https://doi.org/10.1016/j.rasd.2011.01.013

American Psychiatric Association. (2013). Diagnostic and statistical manual of mental disorders (5th ed.). https://doi.org/10.1176/appi.books.9780890425596

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-

Axelsson, E. L., Williams, S. E., & Horst, J. S. (2016). The effect of sleep on

children' s word retention and generalization. Frontiers in Psychology, 7, 1192. https://doi.org/10.3389/fpsyg.2016.01192

Bacon, E. C., Moore, A., Lee, Q., Carter Barnes, C., Courchesne, E., & Pierce, K. (2020). Identifying prognostic markers in autism spectrum disorder using eye tracking. Autism, 24(3), 658–669. https://doi.org/10.1177/1362361319878578

Bal, V. H., Katz, T., Bishop, S. L., & Krasileva, K. (2016). Understanding definitions of minimally verbal across instruments: Evidence for subgroups within minimally verbal children and adolescents with autism spectrum disorder. Journal of Child Psychology and Psychiatry, and Allied Disciplines, 57(12), 1424–1433. https://doi.org/10.1111/jcpp.12609

Baranek, G. T., Woynaroski, T. G., Nowell, S., Turner-Brown, L., DuBay, M., Crais, E. R., & Watson, L. R. (2018). Cascading effects of attention disengagement and sensory seeking on social symptoms in a community sample of infants at-risk for a future diagnosis of autism spectrum disorder. Developmental Cognitive Neuroscience, 29, 30–40. https://doi.org/10.1016/j.dcn.2017.08.006

Bean Ellawadi, A., & McGregor, K. K. (2016). Children with ASD can use gaze to map new words. International Journal of Language & Communication Disorders, 51(2), 212–218. https://doi.org/10.1111/1460-6984.12192

Bhat, A. N., Galloway, J. C., & Landa, R. J. (2010). Social and non-social visual attention patterns and associative learning in infants at risk for autism. Journal of Child Psychology and Psychiatry, and Allied Disciplines, 51(9), 989–997. https://doi.org/10.1111/j.1469-7610.2010.02262.x

Botting, N., & Baraka, N. (2017). Sleep behaviour relates to language skills in children with and without communication disorders. International Journal of Developmental Disabilities, 64(4-5), 238–243. https://doi.org/10.1080/20473869.2017.1283766

Boucher, J., Mayes, A., & Bigham, S. (2012). Memory in autistic spectrum disorder. Psychological Bulletin, 138(3), 458–496. https://doi.org/10.1037/a0026869

Bruner, J. S. (1974). From communication to language—a psychological perspective. Cognition, 3(3), 255–287.

Bruyneel, E., Demurie, E., Warreyn, P., & Roeyers, H. (2019). The mediating role of joint attention in the relationship between motor skills and receptive and expressive language in siblings at risk for autism spectrum disorder. Infant Behavior and Development, 57, 101377. https://doi.org/10.1016/j.infbeh.2019.101377

Campbell, D. J., Shic, F., Macari, S., & Chawarska, K. (2014). Gaze response to dyadic bids at 2 years related to outcomes at 3 years in autism spectrum disorders: A subtyping analysis. Journal of Autism and Developmental Disorders, 44(2), 431–442. https://doi.org/10.1007/s10803-013-1885-2

Carter, C. K., & Hartley, C. (2021). Are children with autism more likely to

retain object names when learning from colour photographs or black-and-white cartoons? Journal of Autism and Developmental Disorders, 51(9), 3050–3062. https://doi.org/10.1007/s10803-020-04771-2

Çetinçelik, M., Rowland, C. F., & Snijders, T. M. (2021). Do the eyes have it? A systematic review on the role of eye gaze in infant language development. Frontiers in Psychology, 11, 589096. https://doi.org/10.3389/fpsyg.2020.589096

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

Chawarska, K., Macari, S., & Shic, F. (2013). Decreased spontaneous attention to social scenes in 6-month-old infants later diagnosed with autism spectrum disorders. Biological Psychiatry, 74(3), 195–203. https://doi.org/10.1016/j.biopsych.2012.11.022

Chen, C. H., Houston, D. M., & Yu, C. (2021). Parent-child joint behaviors in novel object play create high-quality data for word learning. Child Development, 92(5), 1889–1905. https://doi.org/10.1111/cdev.13620

Choi, B., Leech, K. A., Tager-flusberg, H., & Nelson, C. A. (2018). Development of fine motor skills is associated with expressive language outcomes in infants at high and low risk for autism spectrum disorder. Journal of Neurodevelopmental Disorders, 10(14), 1–11. https://doi.org/10.1186/s11689-018-9231-3

Davis, M. H., & Gaskell, M. G. (2009). A complementary systems account of word learning: Neural and behavioural evidence. Philosophical transactions of the Royal Society of London. Series B, Biological sciences„ 364(1536), 3773–3800. https://doi.org/10.1098/rstb.2009.0111

Edmunds, S. R., Ibanez, L. V., Warren, Z., Messinger, D. S., & Stone, W. L. (2017). Longitudinal prediction of language emergence in infants at high and low risk for autism spectrum disorder. Development and Psychopathology, 29, 319–329. https://doi.org/10.1017/S0954579416000146

Ellis Weismer, S., Lord, C., & Esler, A. (2010). Early language patterns of toddlers on the autism spectrum compared to toddlers with developmental delay. Journal of Autism and Developmental Disorders, 40(10), 1259–1273. https://doi.org/10.1007/s10803-010-0983-1

Field, C., Lewis, C., & Allen, M. L. (2019). Referent selection in children with autism spectrum condition and intellectual disabilities: Do social cues affect word-to-object or word-to-location mappings? Research in Developmental Disabilities, 91, 103425. https://doi.org/10.1016/j.ridd.2019.05.004

Fitch, A., Lieberman, A. M., Luyster, R. J., & Arunachalam, S. (2020). Toddlers' word learning through overhearing: Others' attention matters. Journal of Experimental Child Psychology, 193, 104793. https://doi.org/10.1016/j.jecp.2019.104793

Fletcher, F. E., Knowland, V., Walker, S., Gaskell, M. G., Norbury, C., & Henderson, L. M. (2020). Atypicalities in sleep and semantic consolidation in autism. Developmental Science, 23(3), e12906. https://doi.org/10.1111/desc.12906

Franchini, M., Duku, E., Armstrong, V., Brian, J., Bryson, S. E., Garon, N., & Smith, I. M. (2018). Variability in verbal and nonverbal communication in infants at risk for autism spectrum disorder: Predictors and outcomes. Journal of Autism and Developmental Disorders, 48(10), 3417–3431. https://doi.org/10.1007/s10803-018-3607-9

Gangopadhyay, I., & Kaushanskaya, M. (2020). The role of speaker eye gaze and mutual exclusivity in novel word learning by monolingual and bilingual children. Journal of Experimental Child Psychology, 197, 104878. https://doi.org/10.1016/j.jecp.2020.104878

Gaskell, M. G., & Dumay, N. (2003). Lexical competition and the acquisition of novel words. Cognition, 89(2), 105–132. https://doi.org/10.1016/s0010-0277(03)00070-2

Gernsbacher, M. A., & Morson, E. (2019). Fast mapping is a laboratory task, not a cognitive capacity. Cognitive Neuroscience, 10(4), 223–225. https://doi.org/10.1080/17588928.2019.1573810

Gliga, T., Elsabbagh, M., Hudry, K., Charman, T., & Johnson, M. H. (2012). Gaze following, gaze reading, and word learning in children at risk for autism. Child Development, 83(3), 926–938. https://doi.org/10.1111/j.1467-8624.2012.01750.x

Gliga, T., Skolnick, A., Liersch, U., Charman, T., Johnson, M. H., Bedford, R., & BASIS Team. (2021). Investigating the mechanisms driving referent selection and retention in toddlers at typical and elevated likelihood for autism spectrum disorder. Journal of Child Language, 1–13. Advance online publication. https://doi.org/10.1017/S0305000921000416

Grandgeorge, M., Hausberger, M., Tordjman, S., Deleau, M., Lazartigues, A., & Lemonnier, E. (2009). Environmental factors influence language development in children with autism spectrum disorders. PLoS One, 4(4), e4683. https://doi.org/10.1371/journal.pone.0004683

Habayeb, S., Tsang, T., Saulnier, C., Klaiman, C., Jones, W., Klin, A., & Edwards, L. A. (2021). Visual traces of language acquisition in toddlers with autism spectrum disorder during the second year life. Journal of Autism and Developmental Disorders, 51(7), 2519–2530. https://doi.org/10.1007/s10803-020-04730-x

Haebig, E., Jiménez, E., Cox, C. R., & Hills, T. T. (2021). Characterizing the early vocabulary profiles of preverbal and minimally verbal children with autism spectrum disorder. Autism, 25(4), 958–970. https://doi.org/10.1177/1362361320973799

Hartley, C., Bird, L. A., & Monaghan, P. (2019). Investigating the relationship between fast mapping, retention, and generalisation 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

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

He, A. X., Huang, S., Waxman, S., & Arunachalam, S. (2020). Two-year-olds consolidate verb meanings during a nap. Cognition, 198, 104205. https://doi.org/10.1016/j.cognition.2020.104205

Henderson, L., Powell, A., Gaskell, M. G., & 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

Hillairet de Boisferon, A., Tift, A. H., Minar, N. J., & Lewkowicz, D. J. (2018). The redeployment of attention to the mouth of a talking face during the second year of life. Journal of Experimental Child Psychology, 172, 189–200. https://doi.org/10.1016/j.jecp.2018.03.009

Hudac, C. M., DesChamps, T. D., Arnett, A. B., Cairney, B. E., Ma, R., Webb, S. J., & Bernier, R. A. (2018). Early enhanced processing and delayed habituation to deviance sounds in autism spectrum disorder. Brain and Cognition, 123, 110–119. https://doi.org/10.1016/j.bandc.2018.03.004

James, E., Gaskell, M. G., Weighall, A., & Henderson, L. (2017). Consolidation of vocabulary during sleep: The rich get richer? Neuroscience and Biobehavioral Reviews, 77, 1–13. https://doi.org/10.1016/j.neubiorev.2017.01.054

Jiménez, E., Haebig, E., & Hills, T. T. (2021). Identifying areas of overlap and distinction in early lexical profiles of children with autism spectrum disorder, late talkers, and typical talkers. Journal of Autism and Developmental Disorders, 51(9), 3109–3125. https://doi.org/10.1007/s10803-020-04731-w

Johnels, J. A., Gillberg, C., Falck-Ytter, T., & Miniscalco, C. (2014). Face-viewing patterns in young children with autism spectrum disorders: Speaking up for the role of language comprehension. Journal of Speech, Language, and Hearing Research, 57(6), 2023–2035. https://doi.org/10.1044/2014_{JSLHR}-L-13-0138

Jones, W., & Klin, A. (2013). Attention to eyes is present but in decline in 2-6-month-old infants later diagnosed with autism. Nature, 504(7480), 427–431. https://doi.org/10.1038/nature12715

Joseph, R. M., Skwerer, D. P., Eggleston, B., Meyer, S. R., & Tager-Flusberg, H. (2019). An experimental study of word learning in minimally verbal children and adolescents with autism spectrum disorder. Autism & Developmental Language Impairments, 4, 1–13. https://doi.org/10.1177/2396941519834717

Kleberg, J. L., Thorup, E., & Falck-Ytter, T. (2017). Reduced visual disengagement but intact phasic alerting in young children with autism. Autism Research, 10(3), 539–545. https://doi.org/10.1002/aur.1675

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

Kujala, T., Aho, E., Lepistö, T., Jansson-Verkasalo, E., Nieminen-von Wendt, T., von Wendt, L., & Näätänen, R. (2007). Atypical pattern of discriminating sound features in adults with Asperger syndrome as reflected by the mismatch negativity. Biological Psychology, 75(1), 109–114. https://doi.org/10.1016/j.biopsycho.2006.12.007

Landau, B., Smith, L. B., & Jones, S. S. (1988). The importance of shape in early lexical learning. Cognitive Development, 3, 299–321.

Lewkowicz, D. J., & Hansen-Tift, A. M. (2012). Infants deploy selective attention to the mouth of a talking face when learning speech. Proceedings of the National Academy of Sciences of the United States of America, 109(5), 1431–1436. https://doi.org/10.1073/pnas.1114783109

Liu, Q., Wang, Q., Li, X., Gong, X., Luo, X., Yin, T., Liu, J., & Yi, L. (2021). Social synchronization during joint attention in children with autism spectrum disorder. Autism Research, 14(10), 2120–2130. https://doi.org/10.1002/aur.2553

Luyster, R., Lopez, K., & Lord, C. (2007). Characterizing communicative development in children referred for autism spectrum disorders using the MacArthur-Bates Communicative Development Inventory (CDI). Journal of Child Language, 34(3), 623–654. https://doi.org/10.1017/s0305000907008094

Maes, P., Stercq, F., & Kissine, M. (2021). Attention to intentional versus incidental pointing gestures in young autistic children: An eye-tracking study. Journal of Experimental Child Psychology, 210, 105205. https://doi.org/10.1016/j.jecp.2021.105205

Marchman, V. A., Adams, K. A., Loi, E. C., Fernald, A., & Feldman, H. M. (2016). Early language processing efficiency predicts later receptive vocabulary outcomes in children born preterm. Child Neuropsychology, 22(6), 649–665. https://doi.org/10.1080/09297049.2015.1038987

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. Advance online publication. https://doi.org/10.1007/s10803-021-05321-0

McGregor, K. K., Rost, G., Arenas, R., Farris-Trimble, A., & Stiles, D. (2013). Children with ASD can use gaze in support of word recognition and learning.

Journal of Child Psychology and Psychiatry, and Allied Disciplines, 54(7), 745–753. https://doi.org/10.1111/jcpp.12073

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

Nyström, P., Thorup, E., Bölte, S., & Falck-Ytter, T. (2019). Joint attention in infancy and the emergence of autism. Biological Psychiatry, 86(8), 631–638. https://doi.org/10.1016/j.biopsych.2019.05.006

Paparella, T., Goods, K. S., Freeman, S., & Kasari, C. (2011). The emergence of nonverbal joint attention and requesting skills in young children with autism. Journal of Communication Disorders, 44(6), 569–583. https://doi.org/10.1016/j.jcomdis.2011.08.002

Reinhartsen, D. B., Tapia, A. L., Watson, L., Crais, E., Bradley, C., Fairchild, J., Herring, A. H., & Daniels, J. (2019). Expressive dominant versus receptive dominant language patterns in young children: Findings from the study to explore early development. Journal of Autism and Developmental Disorders, 49(6), 2447–2460. https://doi.org/10.1007/s10803-019-03999-x

Russo, S., Calignano, G., Dispaldro, M., & Valenza, E. (2021). An integrated perspective on spatio-temporal attention and infant language acquisition. International Journal of Environmental Research and Public Health, 18(4), 1592. https://doi.org/10.3390/ijerph18041592

Spiegel, C., & Halberda, J. (2011). Rapid fast-mapping abilities in 2-year-olds. Journal of Experimental Child Psychology, 109(1), 132–140. https://doi.org/10.1016/j.jecp.2010.10.013

Stanovich, K. E. (1986). Matthew effects in reading: Some consequences of individual differences in the acquisition of literacy. Reading Research Quarterly, 21(4), 360–407.

Su, Y. E., Naigles, L. R., & Su, L. Y. (2018). Uneven expressive language development in mandarin-exposed preschool children with ASD: Comparing vocabulary, grammar, and decontextualized use of language via the PCDI-Toddler Form. Journal of Autism and Developmental Disorders, 48(10), 3432–3448. https://doi.org/10.1007/s10803-018-3614-x

Suarez-Rivera, C., Smith, L. B., & Yu, C. (2019). Multimodal parent behaviors within joint attention support sustained attention in infants. Developmental Psychology, 55(1), 96–109. https://doi.org/10.1037/dev0000628

Takashima, A., Bakker, I., van Hell, J. G., Janzen, G., & McQueen, J. M. (2017). Interaction between episodic and semantic memory networks in the acquisition and consolidation of novel spoken words. Brain and Language, 167, 44–60. https://doi.org/10.1016/j.bandl.2016.05.009

Tecoulesco, L., Fein, D., & Naigles, L. R. (2021). What categorical induction

variability reveals about typical and atypical development. Journal of Child Language, 48(3), 515–540. https://doi.org/10.1017/S0305000920000392

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

Tenenbaum, E. J., Amso, D., Righi, G., & Sheinkopf, S. J. (2017). Attempting to "Increase Intake from the Input" : Attention and word learning in children with autism. Journal of Autism and Developmental Disorders, 47(6), 1791–1805. https://doi.org/10.1007/s10803-017-3098-0

Tomasello, M., & Farrar, M. J. (1986). Joint attention and early language. Child Development, 57(6), 1454–1463.

Tovar, A. E., Rodriguez-Granados, A., & Arias-Trejo, N. (2020). Atypical shape bias and categorization in autism: Evidence from children and computational simulations. Developmental Science, 23(2), e12885. https://doi.org/10.1111/desc.12885

Tsang, T., Atagi, N., & Johnson, S. P. (2018). Selective attention to the mouth is associated with expressive language skills in monolingual and bilingual infants. Journal of Experimental Child Psychology, 169, 93–109. https://doi.org/10.1016/j.jecp.2018.01.002

Venker, C. E. (2017). Spoken word recognition in children with autism spectrum disorder: The role of visual disengagement. Autism, 21(7), 821–829. https://doi.org/10.1177/1362361316653230

Venker, C. E. (2019). Cross-situational and ostensive word learning in children with and without autism spectrum disorder. Cognition, 183, 181–191. https://doi.org/10.1016/j.cognition.2018.10.025

Venker, C. E., Bean, A., & Kover, S. T. (2018). Auditory-visual misalignment: A theoretical perspective on vocabulary delays in children with ASD. Autism Research, 11(12), 1621–1628. https://doi.org/10.1002/aur.2038

Venker, C. E., Mathee, J., Neumann, D., Edwards, J., Saffran, J., & Ellis Weismer, S. (2021). Competing perceptual salience in a visual word recognition task differentially affects children with and without autism spectrum disorder. Autism Research, 14(6), 1147–1162. https://doi.org/10.1002/aur.2457

Vlach, H. A., & DeBrock, C. A. (2019). Statistics learned are statistics forgotten: Children' s retention and retrieval of cross-situational word learning. Journal of Experimental Psychology: Learning, Memory, and Cognition, 45(4), 700–711. https://doi.org/10.1037/xlm0000611

Walker, S., Henderson, L. M., Fletcher, F. E., Knowland, V. C. P., Cairney, S. A., & Gaskell, M. G. (2019). Learning to live with interfering neighbours: The influence of time of learning and level of encoding on word learning. Royal Society Open Science., 6(4), 181842. https://doi.org/10.1098/rsos.181842

Wang, S., Jiang, M., Duchesne, X. M., Laugeson, E. A., Kennedy, D. P., Adolphs, R., & Zhao, Q. (2015). Atypical visual saliency in autism spectrum disorder quantified through model-based eye tracking. Neuron, 88(3), 604–616. https://doi.org/10.1016/j.neuron.2015.09.042

Weighall, A. R., Henderson, L. M., Barr, D. J., Cairney, S. A., & Gaskell, M. G. (2017). Eye-tracking the time-course of novel word learning and lexical competition in adults and children. Brain and Language, 167, 13–27. https://doi.org/10.1016/j.bandl.2016.07.010

Young, G. S., Merin, N., Rogers, S. J., & Ozonoff, S. (2009). Gaze behavior and affect at 6 months: Predicting clinical outcomes and language development in typically developing infants and infants at risk for autism. Developmental Science, 12(5), 735–748. https://doi.org/10.1111/j.1467-7687.2009.00833.x

Yu, C., & Smith, L. B. (2012). Embodied attention and word learning by toddlers. Cognition, 125(2), 244–262. https://doi.org/10.1016/j.cognition.2012.06.016

Yu, C., Suanda, S. H., & Smith, L. B. (2019). Infant sustained attention but not joint attention to objects at 9 months predicts vocabulary at 12 and 15 months. Developmental Science, 22(1), e12735. https://doi.org/10.1111/desc.12735

Note: Figure translations are in progress. See original paper for figures.