Associative Word Learning Predicts Later Vocabulary Development: A Longitudinal Investigation

Abstract

Following prior research demonstrating the relationship between children's early processing and learning abilities and their language and cognitive skills later in life, this longitudinal study examined whether associative word learning ability in the first year after birth was predictive of their later linguistic performance. Fifty-one typically developing Australian English-learning first-year infants participated in an associative word learning task in which their ability to associate non-native tones with novel objects was examined. When participants reached 6 to 7 years, their vocabulary scores were assessed via the Peabody Picture Vocabulary Test (fourth edition). Although no robust associative word learning was observed in infancy, a positive correlation between infants' learning outcomes and later vocabulary size was observed. As the learning targets were non-native to infants, we argue that the ability to associate new sounds with new information may serve as one of the learning mechanisms that drive children's word development across ages in addition to language-specific mechanisms and language-induced developmental changes.

***Keywords*:**

associative word learning; vocabulary development, language development, early predictor, lexical tone

1. Introduction

Early childhood development is influenced by children's inherited genetic makeup and the environment in which they are immersed. Language acquisition is a prime example of human development through biological and environmental contexts. Infants and toddlers tune in to the statistical and perceptual regularities of their native language (Reh et al., 2020), and sensitivity to patterns absent from their ambient surrounds deteriorates (Fort et al., 2017). Although prior studies have extensively examined the early development of sounds (Kuhl et al., 2006), words (Bergelson & Swingley, 2015; Rowe, 2012) and their associations (Stager & Werker, 1997), the extent to which children's early non-native language learning ability can predict later linguistic performance remains unclear. The current study pioneered an investigation into the relationship between first-year infants' associative learning of non-native words and their vocabulary development at 6-7 years.

Word learning plays a vital role in children's language and cognitive developmental trajectory (Swingley, 2009). From statistical (Saffran et al., 1996; Saffran et al., 1999) and relational (Ferry et al., 2015; Hespos & Spelke, 2004) learning to mutual exclusivity (Markman & Wachtel, 1988; Kalashnikova et al., 2016), children use innate and adaptive learning mechanisms to expand their vocabulary and their knowledge of the world. They demonstrate understanding of familiar words at 6 months (Bergelson & Swingley 2012) and recognise spoken words regardless of what volume and tone they were spoken in at 9 months (Singh, Nestor et al., 2008). At 11 months, infants recognise words by new speakers and speakers of different genders (Singh, White et al., 2008), as well as words previously encountered and reject word mispronunciations at 15 months (Yoshida et al., 2009). Eighteen-month-olds were able to use the form of a word to determine its meaning (Swingley, 2007). Although there is great individual variation (McMurray, 2007), steep growth in vocabulary occurs in the second half of the second year of life (Fernald & Marchman, 2011; Goldfield & Reznick, 1990;

Reznick & Goldfield, 1992). By year 2, children have a productive vocabulary of around 200-300 words (Kalashnikova et al., 2024), which develops exponentially as they age. While researchers often adopt validated tools such as the MacArthur-Bates Communicative Development Inventory (CDI, Fenson, 2007) to measure young children's lexical development, older children are often tested on friendly, graph-based designs such as the Peabody Picture Vocabulary Test (PPVT, Dunn & Dunn, 1965) and its later versions.

While infants demonstrate remarkable sensitivity to phonetic contrasts across world languages in the first half of the first year of life, they quickly attune to phonetic variations and word patterns of their native language (Gervain & Mehler, 2010; Jusczyk, 1995), and tune out to patterns absent from their native linguistic repertoire (Polka & Werker, 1994; Werker & Tees, 1984) in the second half of the first year after birth. This process, often termed perceptual attunement, has been argued to be domain general (Scott et al., 2007), reflecting adaptive changes in neurocognitive plasticity in relation to the environment young children face (Kuhl et al., 2006; Werker & Hensch, 2015). In other words, children become proficient learners of their own environments as they grow, whereas their ability to discern perceptual differences absent from their ambient environment generally deteriorate (Reh et al., 2020).

The attunement process is modulated by various factors, such as the perceptual salience of learning targets, leading to variations in perception and learning speed and outcomes along the developmental trajectories (Tsao, 2017). Taking lexical tone as an example, lexical tone refers to pitch variations on a lexical level to change core word meanings (Yip, 2002). This feature is present in tone languages where two words can differ solely by tonal differences (e.g., in Mandarin /ma/ in flat tone means "mother" and in dipping tone means "horse") but absent in non-tone languages like Dutch or English in which pitch changes typically refer to paralinguistic rather than lexical differences (Liu et al., 2022). Against prediction, infants exhibited continuous sensitivity to a salient, non-native tone contrast from 5 to 18 months.

Sensitivity has been found to decrease from 5 to 9 months only when the salience of the contrast was reduced, thus adhering to perceptual patterns predicted by attunement frameworks (Liu & Kager, 2014). The latter finding converges with studies marking that the perceptual attunement of tones occurs approximately between 3-6 and 9-12 months (Fikkert et al., 2020; Yeung et al., 2013).

The ambient environment encompasses a wide array of experiences from auditory and visual information to interpersonal interactions (Duff et al., 2015). To learn words, children need to associate objects or concepts with their corresponding word or sound forms. This is referred to as associative word learning. As early as 6 months, infants demonstrated astonishing ability to use prosodic phrase boundary in continuous speech as a cue to segment sounds and map them onto visual objects as their names (Shukla et al., 2011). When a specific sound was consistently associated with a particular object, and a different sound with another object, 9-month-olds showed enhanced discrimination to this sound contrast albeit it was non-native (Yeung & Werker, 2009; Yeung et al., 2014). The authors argue that the enhancement may be due to learning two sounds at the same time which may have enlarged their perceptual distance and increased their distinctiveness (Kluender et al., 1998).

Essential to language development, children's associative word learning follows the perceptual attunement trajectory (Cumming et al., 2009). As they age, children become better at associating native speech sounds with novel objects. Seventeen-month-olds succeeded in associating novel objects with minimal pairs ([bih] vs. [dih]), that is, sounds with minimal differences that can potentially change word meanings in infants' native language (Stager & Werker, 1997; Werker et al., 1998), and were able to map freshly segmented words but not part- or non-words onto novel objects. (Estes et al., 2007). A recent meta-analysis involving 2,723 participants aged 12 to 20 months demonstrated infants' associative word learning ability across ages with native sound contrasts, and younger infants benefit more from additional facilitative cues (e.g., dissimilar-over similar-sounding words) than older infants (Tsui et al., 2019). Meanwhile, when associating objects with sounds from a non-native language that do not conform to infants' native phonemic inventory, a pattern of deterioration has been observed. Fourteen-month-old Dutch- and English-learning infants were able to associate novel objects with non-native tones, but were unable to do so at 18 months (Hay et al., 2014; 2019; Liu & Kager, 2018). As tones are not lexically relevant to these infants, these observations adhere to the perceptual attunement framework.

Typically, the areas of associative word learning and vocabulary development have been examined individually in early childhood. Nevertheless, converging evidence suggests that children's early language experiences and learning ability are likely linked with their vocabulary development and language processing ability (Weisleder & Fernald, 2013). Werker et al. (2002) examined the effects of second-year infants' age and vocabulary size on their abilities to associate similar-sounding words with novel objects in a synchronic fashion. Vocabulary size predicted word learning among 14-month-olds but not older infants. Findings raise the question as to whether such a relationship would surface in a diachronic setting.

The investigation of predictive relationships between early indicators and subsequent language abilities is of central interest to the study of human cognition. Studies adopting a longitudinal design have explored such relationships across children's speech perception, word learning, and language and cognitive development. First-year infants' speech perception ability has been shown to predict their vocabulary development in the second year (Benasich & Tallal, 2002; Singh et al., 2012; Tsao et al., 2004), and vice versa. Children's associative word learning ability measured at 17 or 20 months was significantly related to their language comprehension and production ability at 3-4 years (Bernhardt et al., 2007). The referential transparency of parent-child interactions at 14-18 months, as assessed by how well independent observers could guess what the parent was saying in muted videos of these interactions, correlated with child vocabulary size at 4.5 years (Cartmill et al., 2013). Children's word segmentation ability from continuous speech predicted their expressive vocabulary measured by CDI at 24 months, and further to language skills at 4-6 years (Newman et al., 2006), and their expressive vocabulary scores measured by CDI at 22 months contribute to 17% of the variance of their letter-naming fluency performance at 6 years (Can et al., 2013). Children' associative word learning outcomes at 21 months contributed to 22% of the variance receptive vocabulary measured by the fourth version of PPVT (PPVT-4; Dunn & Dunn, 2007) at 7-10 years (Rajan et al., 2019). Further, a correlation was observed between second-year infants' lexical and grammatical development, and subsequently, their language processing speed at 25 months (Fernald et al., 2006), and speech processing and vocabulary size at 25 months further predicted children's language, cognition, and working memory assessment outcomes at 8 years (Marchman & Fernald, 2008).

Similar observations extended from typically developing children to those at risk for developmental disabilities. Associative word learning outcomes among 16-24-month-old typically developing children and children at risk of language delay were correlated with their productive vocabulary and speech production results at 27 months (Kemp et al., 2017). Moreover, lexical processing speed measured at 18 months predicted infants' expressive vocabulary size at 30 months regardless of whether they were born full or preterm (Marchman et al., 2019). This measure, as well as preterm infants' socioeconomic status, predicted preterm infants' receptive vocabulary measured by PPVT-4 at 3 years (Marchman et al., 2016), and their language and cognitive abilities measured at 4.5 years (Marchman et al., 2018). Furthermore, children with autism spectrum disorder's word processing measured by electroencephalogram at 2 years predicted their receptive language and cognitive ability at 4 and 6 years (Kuhl et al., 2013).

Across the above-mentioned studies examining children from diverse ages and language and health backgrounds, performance in children's native language were assessed. The extent to which children's ability to learn new information from a non-native language would predict native language outcomes remains unclear. Having said that, traces surface in speech perception studies, where research target how children perceive native and non-native speech. A magnetoencephalography study has reported that 7-month-olds' non-native but not native speech processing was a significant predictor of their vocabulary growth from 12 to 30 months (Zhao & Kuhl, 2022), leading to the hypothesis that early non-native word learning may also follow this predictive pattern. Nevertheless, other speech perception studies conducted by the authors reported an opposite trend, that is, better early native speech processing predicted later positive vocabulary development, whereas better early non-native speech processing predicted later negative vocabulary development (Kuhl et al., 2005; Kuhl et al., 2008; Zhao et al., 2021). While the authors attributed the discrepancy to stimuli being more acoustically instead of linguistically perceived in their 2022 study, the contrasting findings warrant further thinking and examination.

As speech perception and word learning develop hand-in-hand, the abovementioned discrepancy raises interesting theoretical questions. If children's language developmental trajectory and learning mechanisms strictly adhere to perceptual attunement, then better non-native perception and learning may indicate a slower pace of native language development. Similar arguments have been raised when targeting bilingual population, who have been hypothesised to have a later and more flexible attunement offset comparing to their monolingual peers given their complex language environments (Liu & Kager, 2017; Petitto et al., 2012). Nevertheless, another possibility needs to be considered given the finding of Zhao and Kuhl (2022), that is, at least some underlying mechanisms of language development should be language- or perhaps domain-general, facilitating perception and learning regardless of nativeness of the target input. Children's perceptual sensitivity to amplitude envelope rise time (which marks the onset of new phonological units in speech) at 7 and 10 months predicted their vocabulary at 3 years (Kalashnikova et al., 2019), and their acoustic sensitivity may be attributed to the positive relationship with vocabulary development (Zhao & Kuhl, 2022).

The present study assessed the extent to which early language learning is predictive of later linguistic performance. Using a non-native contrast, this study was set to examine whether associative learning ability should be seen as an innate learning mechanism that is language-general, and likely beyond the language domain on par with statistical and relational learning. Following different perceptual patterns observed between the first and second half of the first year of life, two age groups were examined. The first aim of the study was to examine the non-native associative word learning ability among two groups (5-6 months, 11-12 months) of first-year infants. More importantly, following previous longitudinal studies reporting predictive relationships between perception and learning of native languages (Marchman & Fernald, 2008), the second aim was to determine whether children's early performance on non-native sound-novel object association could be predictive of their vocabulary development at 6-7 years. Combining these two aims, our last aim was to investigate whether children's age at the initial assessment would moderate later outcomes.

2. Methodology

2.1. Participants

Fifty-one typically developing, monolingual Australian English-learning infants (41.2% female) aged 5-6 (n = 26) and 11-12 months (n = 25) were recruited from the Western Sydney University MARCS BabyLab registry. The sample size adheres to the a priori power analysis required to test the study hypothesis using G*Power version 3.1.9.7 (Faul et al., 2007) to achieve 90% power for detecting a small-to-medium effect (f = 0.25), at a significance criterion of α = .05. Another eleven infants were omitted for fussiness (*n* = 2), crying (*n* = 3), inattentiveness (*n* = 1), family history of dyslexia (*n* = 1), and not meeting the habituation criterion in the associative word learning experiment (*n* = 4). All 51 participants were recontacted for follow-up assessments when they reached 6-7 years of age, among whom 16 completed a follow-up examination (accounting for 31.4% of the original sample). These participants were from the 5-6-month-old younger infant age group (33.3% female, *n* = 9, mean age of M = 6.51 years, SD = 0.23 years, accounting for 34.62% of the original sample) and from the 11-12-month-old older infants age group (42.8% female, *n* = 7, with a mean age of M = 6.67 years, SD = 0.32 years, accounting for 28.00% of the original sample). Reasons for non-participation included unable to reach participants (*n* = 16), lack of available time to complete research (*n* = 11), and unable to continue due to personal reasons (*n* = 8). Ethics approval was attained for the initial study and follow-up assessment from the Human Ethics Research Committee at Western Sydney University.

2.2. Measures / Stimuli

2.2.1. Associative Word Learning

The associative word learning (or intermodal preferential looking paradigm) involves auditory and visual information novel to participants. In the pre- and post-test phases, infants viewed a ball moving horizontally along with auditory tokens of the word “ball”. In the habituation and test phases, a Mandarin tone contrast was used to create the auditory stimuli used in the experiment. A syllable /ta/ was selected as the focal unit for tonal analysis, as its flat tone (meaning: “take”) and falling tone (meaning: “big”) are legitimate linguistic entities in Mandarin. The vocal performance of a Mandarin-speaking female was captured through the software Audacity using a Genelec 1029A active speaker recording arrangement within a sound-isolated chamber at the phonetics laboratory of Utrecht University. Natural productions of /ta/ in flat and falling tones were acquired, and four tokens from each tone were selected to create four flat-falling contrasts. As the flat-falling contrast (Figure 1 left, contrast A) was perceptually salient to non-native tone language learners (Liu & Kager, 2014) and listeners (Huang & Johnson, 2011), its fundamental frequency was contracted via the software PRAAT (Boersma & Van Heuven, 2001): Four interpolation points were marked at 0%, 33%, 66%, and 100% positions of the pitch contour, and the fundamental frequency values at 3/8 and 3/4 distances of the contrast were computed at these interpolation points. Two new pitch contours were generated by connecting the corresponding interpolation points (Figure 1 left, contrast B). This new contrast featured a narrower distance between the pitch contours, reducing contrast salience. Its oscillograms and spectrograms are shown in Figure 1 (right). With respect to the visual stimuli, two unfamiliar objects were used in each experiment (see Figure 2 for an example). The visual stimuli and their pairings with the audio stimuli were counterbalanced across participants.

2.2.2. Childhood Receptive Vocabulary

The Peabody Picture Vocabulary Test – 4th edition (Dunn & Dunn, 2007) was used to measure the lexical proficiency of the participant in the follow-up phase. PPVT-4 is an untimed and individually administered test that consists of 228 items and word choices divided into 19 sets of 12 items that gradually increase in difficulty as participants progress through the test. Participants were required to match the picture on the screen with the word that best describes the image. Participants’ responses formed the raw scores, which were further converted into standard scores, percentile ranks, and age equivalents by being compared to normative data. Higher standard scores equated to better receptive vocabulary abilities in childhood.

2.3. Procedure

2.3.1. Associative Word Learning

The laboratory and habituation setups (Figure 2) of the current study were the same as those used by Liu and Kager (2018). In the testing booth, infants were seated on their caregivers' lap approximately one meter away from the testing devices, including three flat-screen monitors in a row, two speakers hidden behind the central monitor, and a hidden camera underneath the central monitor. The equipment in the testing booth was connected to an external computer and monitors in the control room, allowing the experiment to view and record infants' looking time responses. The software Habit (Oakes et al., 2019) was run to present the audio-visual stimuli on the monitors in the testing booth. The experimenter indicated when infants looked at the stimuli at these monitors through button press via Habit. To reduce bias, caregivers were masked by listening to music over headphones during the experiment, and the experimenter was blind to stimuli and conditions presented.

To get familiarised with the paradigm, infants first viewed two 10-second pre-test trials during which a moving ball appeared on one side (left or right) screen pairing with sound tokens of the word "ball" in one trial, and a moving car appeared in the opposite side screen pairing with sound tokens of the word "car" in the other trial. The trial orders and screen presentation were counterbalanced across participants.

The associative word learning occurred in the habituation phase of the experiment, where a total two label-object pairings were presented but each trial only consisted of one pairing. In each trial, infants heard one sound label presented repeatedly with an interstimulus interval of one second while seeing one of the two unfamiliar objects moving on the left or right screen. The trial was measured by infant gaze, with a maximum possible time of 20 seconds. Each trial was terminated once the infant's gaze was averted for two seconds. The label-object pairings and the screen of the visual stimuli appearances were counterbalanced. If the visual stimulus of the first mapping appeared on the left screen, that of the second mapping would appear on the right screen. The habituation criterion was reached when infants' looking times to both pairings dropped to 65% of their initial looking times to the corresponding pairings, and infants immediately moved on to the test phase.

The test phase consisted of four trials where both objects were presented each at one side screen, while only one sound label was played. In each trial, infants' looking time at both objects were recorded. Longer looking at the original pairing, namely, the object that was associated with the sound label in the habituation phase, would indicate successful learning of the correct sound-object association. In other words, the percentage of correctness each trial was computed as the looking time at correct object / (looking time at correct object + looking time at incorrect object). The location of objects and occurrences of sound stimuli were counterbalanced across trials and participants.

The experiment ends with a post-test phase where the same audio-visual stimuli as in the pre-test trials were played to ensure that infants' overall attention was kept throughout the experiment.

2.3.2. PPVT-4

Caregivers who participated in the first experiment were contacted via an email address that had been stored on the Western Sydney University MARCS Babylab registry from their initial participation. Caregivers were asked to complete demographic questionnaires about their children. Participating children engaged in the PPVT-4 assessment independently through Q-Global, a web-based platform by Pearson education company for test administration, scoring, and reporting. Children used their personal computers under the supervision of their parents to complete the PPVT-4.

To complete the PPVT-4, participants were presented with images and tasked with selecting the appropriate words from the provided choices. The task was leveled based on the difficulty of words typically known to children, such that words appearing earlier were typically easier to identify than words appearing later. The test continued until the participant got a certain number of choices wrong in a level, at which point a raw score was computed. Upon successful completion of the test, participants were thanked with a gift card for their time.

2.4. Analyses

To assess the first aim on infants' associative word learning ability in the first year after birth, the two infant age groups were included: specifically, younger infants and older infants. To investigate the differences in word learning abilities between the two age groups, a univariate analysis of variance was conducted on the dependent variable of test performance to determine if mean performance scores for the two age groups differed. Following this, an independent samples t-test was conducted to determine if the performance of each age group was significantly different from a 50% chance level, allowing for the results to be assessed against participants guessing the correct answer.

To examine the second aim regarding whether early associative word learning and later receptive vocabulary would correlate, a bivariate Pearson's correlation test was conducted on performance scores in the associative word learning task and the PPVT.

To examine the third aim on the detailed relationship between early associative word learning and later receptive vocabulary, a hierarchical multiple regression was conducted. In step 1, age was entered. In step 2, performance scores from the associative word learning task were entered. Finally, in step 3, the two-way interaction between age and the performance score from the associative word learning task were entered.

3. Results

To investigate infants' associative word learning ability in the first year (see Table 1 for descriptive statistics), a univariate analysis of variance measuring the mean test scores by the between-subject factor of the infant age group showed there were no significant differences in the mean word learning abilities by infant age group, $F\,(1,39) = 0.161$, $p = .690$, $\eta p2 = 0.004$. The proportion of variance explained by the model was minimal, with an $R^2 = 0.004$. These results indicate no significant difference between the two age groups (see Figure 3). For the 5-6-month-old infants, performance was not statistically different from the (50%) chance level (M = 53.6%, SD = 12.2%). Results of the independent samples t-test were not significantly different from the baseline, $t\,(21) = 1.387$, $p = .180$. The 11-12-month-old infants' performance was not statistically different from the (50%) chance level (M = 52.2%, SD = 9.4%). These results were not significantly different from the baseline, $t\,(21) = 1.028$, $p = .317$).

Children from families who participated in the PPVT-4 task received an average standard score of 122, which was one standard deviation (85-115) above average (100 as the standard mean), indicating that they were good native language learners. These participants exhibited higher mean percentage of looking time at the correct object (57%, Table 2) in the associative word learning task ($t\,(15) = 2.826$, $p = .013$) than all infants who completed that task (Table 1) which was not different from looking to the correct object at a chance level (50%).

Connecting infants' early word learning abilities with their childhood receptive vocabulary longitudinally (see Table 2 for descriptive statistics), a positive relationship between the associative word learning task scores and the PPVT scores was found, $r\,(16) = .622$, $p = .010$ (see Figure 4 for individual datapoints). Further, the hierarchical linear regression on the impact of age and the associative word learning task performance on PPVT scores is shown in Table 3. In step 1, Age Group (two-level, 5-6m vs 11-12m) was entered into the model and was not significant, F (1, 14) = 0.09, p = .775, explaining 0.6% of the variance in PPVT standard score (R^2 = .006, adjusted R^2 = -.065). In step 2, early performance in associative word learning task was added into the model, significantly improving the model, F (1, 13) = 8.08, p = .014. The final model accounted for 38.7% of the variance in PPVT scores (R^2 = .387, adjusted R^2 = -.293).

Last but not least, to understand whether child age at the initial assessment moderates the relationship between associative word learning and vocabulary in later childhood, greater PPVT scores were predicted by word learning (Table 3), which explained 39% variance (R^2 = .39, adjusted R^2 = .29, F (5, 38) = 4.51, p = .003). For every 0.1 increase in the proportion correct on the word learning task (i.e., an increase of 10% correct), PPVT scores increased by 7.735 points. That is, as word learning accuracy changes by 10% correct, there is a corresponding 7.735-point increase in PPTV scores. The addition of the interaction term did not improve model fit, R^2 change < 0.01, p = .944.

4. Discussion

This study investigated first-year infants' non-native word learning ability and its relationship with vocabulary size later at 6-7 years. Overall, results showed no evidence differentiating infants' non-native word learning ability at 5-6 and 11-12 months, nor was age a significant factor modulating later vocabulary scores. Crucially, regardless of the age at which infants' associative word learning ability was examined, better associative learning of non-native words in infancy was associated with, and predicted, greater receptive vocabulary in later childhood.

When investigating associative word learning, prior studies have typically focused on second-year infants (Tsui et al., 2019) during which their vocabularies grow exponentially

(McMurray, 2007; Sloutsky et al. 2017). With respect to non-native speech contrasts, prior studies point to a decrease in associative word learning ability at this stage. For instance, non-tone language-learning infants associated lexical tones with novel objects at 9-months (Yeung et al., 2014) and 14-months but not after 18-months (Hay et al., 2014; Liu & Kager, 2018). These observations are in line with the perceptual attunement framework suggesting the role of experience in language acquisition (Werker & Hensch, 2015) and neurocognitive development (Kuhl, 2010). Studies reporting associative word learning patterns among first-year infants are scarce. Different from Yeung et al. (2014), our results revealed no robust learning at this stage, both 5-6- and 11-12-month-olds looked at sound-matched objects at chance level. Results related to this null finding need to be interpreted with high caution as the absence of evidence does not serve as the evidence of absence. The first explanation to account for this finding is that the current results may reflect the rapidity with which infants abandoned non-native phonemes along the attunement process. However, infants' success at 14 months (Hay et al., 2014; Liu & Kager, 2018) suggests that they should still be plastic in accepting tonal variations as plausible word units before that age.

Another possibility is that first-year infants are focused more on establishing speech categories (i.e., learning to classify phonetic differences from exemplars in different contexts) than on establishing word meanings (Kuhl, 2004). Infants undergo rapid neural and cognitive development in the first year after birth (Scott & Brito, 2022). They may rely more on learning mechanisms that are more helpful for establishing sound categories, such as statistical learning (Saffran et al., 1996), and less on other learning strategies. However, this explanation cannot fully explain studies reporting infants' success at 9 months (Yeung et al., 2014).

The third explanation lies in task difficulty, which affect perception (Burnham & Singh, 2018) and associative learning outcomes (Stager & Werker, 1997; Tsui et al., 2019). Different tone contrasts were used between the current and previous studies. This study adopted a contrast low in perceptual salience (Liu et al., 2022). In addition, considering cognitive load (Mitterer & Mattys, 2017) and memory load (Zosh & Feigenson, 2012) frameworks, the appearance of both objects and sounds in the test trials may be more cognitively demanding for young infants than the tone discrimination task, where infants are only required to disambiguate auditory information. Adopting a more salient speech contrast than currently used or reducing the task difficulty may lead to better learning outcomes.

Crucial findings emerged when comparing participants' longitudinal results. Children who were better at associative word learning in the first year, regardless of at which age they were tested, showed greater receptive vocabulary in later childhood. This diachronic observation echoes previous studies demonstrating synchronic relationships between early associative word learning or speech processing and later vocabulary and cognitive development (e.g., Werker et al., 2002). Here, differences between the current and prior studies must be addressed. First, although auditory stimuli were novel, previous studies used stimuli that match infants' native phonotactic patterns and concentrated on native language learning, whereas non-native stimuli absent from participants' phonemic inventory were used in the current study, highlighting infants' ability to acquire new associations. This indicates that, rather than language-specific influences or reasons, the predictive relationships observed across studies likely reflect general learning mechanisms and cognitive functions driving human language learning across the developmental trajectory. Here, we hypothesise that children's associative learning ability, the ability to associate novel multi-sensory information, is the underlying mechanism. Similar to statistical learning and relational learning, associative learning is language-general and likely functions beyond the language domain. Similar to mutual exclusivity (Byers-Heinlein & Werker, 2009), associative learning is subject to environment input, as reflected in different outcomes in the course of perceptual attunement.

Second, while some studies computed the degree of variances of early word learning ability on later vocabulary development (e.g., Rajan et al., 2019), our study showed a more direct trend with the correlational relationship between the two. This encouraging finding underscores the possibility that early markers of word learning provide insight into later linguistic capabilities. It is worth noting that while echoing findings from a prior speech perception study exploring the relationship between early processing and later language development (Zhao & Kuhl, 2022), the current study does not contradict previous speech perception findings showing an opposite pattern following perceptual attunement interpretations (Kuhl et al., 2005; Kuhl et al., 2008; Zhao et al., 2021). Rather, it complements these studies by raising the awareness of additional underlying learning mechanisms not specific to which language children learn. To sum up, while previous studies typically measured associative word learning in the second year after birth, results of the current study suggested that other indicators can emerge earlier, in the first year after birth.

Diving into our last aim of the study, although infants' age at initial assessment did not moderate the relationship between associative word learning and receptive vocabulary, the current results (Figure 4) reflect the role of individual differences in language learning (Pérez-Edgar et al., 2020). The first-year results suggest that a relatively broad window may be considered when examining individual infants' language-learning ability to project their future language outcomes. Individual differences in 25-month-old toddlers' word recognition ability were related to their lexical and grammatical development throughout the second year of life (Fernald et al., 2006), echoing the finding that language learning efficiency and ability can predict later linguistic outcomes.

Albeit the interesting findings, a few limitations need to be addressed. First, as Table 2 illustrated, our longitudinal results were arguably drawn from relatively high-performing households. Children who were good at native vocabulary development also performed well at associative learning of non-native words early on. Having said that, if the current sample was categorised as children with learning advantages, our results complement prior studies of typical developing children (Marchman & Fernald, 2008) and children at risk of language delays (Kuhl et al., 2013; Marchman et al., 2016), where similar predictive relationships were reported.

A second limitation lies in the low number of families that agreed to participate in the follow-up study. Although we did our best to encourage families to agree to the additional data collection, we must respect parental attitude and follow the research ethics which stipulated that participation must be entirely voluntary. Our sample size matches some prior research where a similar relationship was observed among 15 participants who joined in the follow-up study from the initial sample of 26 (Bernhardt et al., 2007). Although the high dropout rate is likely caused by the 5-6 year distance between the initial and the follow-up studies, speculation arises that infants' language learning ability may drive parental motivation to participate in the current experiment, as families who agreed to participate in the follow-up study were the ones who were interested in discovering their children's pace of language development as measured by PPVT-4.

A third limitation resides in the previously mentioned null finding in the associative word learning among first-year infants. Apart from considerations from stimuli (e.g., perceptual salience) and procedure (e.g., task difficulty) perspectives, it is worth mentioning that the inclusion of a more diverse participant population (e.g., bilingual infants) may also lead to more positive outcomes (Graf Estes & Hay, 2015; Tsui et al., 2019).

In summary, this study examined whether children's learning of non-native words in the first year predicted the number of words they knew on the PPVT-4 at 6-7 years of age. Adopting a longitudinal design, the study allows for a unique opportunity to track developmental changes and assess the consistency and stability of early predictors over time, while providing insight into the continuity of language abilities from infancy to childhood. Children's early performance was indeed predictive of their vocabulary scores in later childhood, indicating the importance of early language capabilities on child development. While other studies benchmark early speech perception, lexical processing and word recognition as predictors for later language development, our experiment suggests that early associative learning ability can also fulfill this role. Further, as a non-native contrast was used, the underlying mechanisms of associative learning that drive children's language development is deemed language- and perhaps domain-general. Language acquisition is influenced by learning and representational principles that are common across ages. These results welcome further discussions about the implications of the time and extent to which early language interventions may be identified and begin (Kemp et al., 2017).

5. References

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Table 1

Descriptives of the associative word learning task for infants at 5-6 and 11-12 months.

Mean age (year)	**SD age** (year)	**Mean correctness** (perc)	**SD correctness** (perc)
0.49	0.04	53.62%	12.23%
0.98	0.04	52.23%	9.45%

Table 2

Descriptives of participants who attended both tasks longitudinally.

Associative Word Learning Task				Peabody Picture Vocabulary Test					
Mean age (year)	SD age (year)	Mean correctness (perc)	SD correctness (perc)	Mean age (year)	SD age (year)	Raw score	Standard score	95% CI (low)	95% CI (high)
0.48	0.06	57.28%	10.13%	6.51	0.24	139	124	116	130
0.99	0.03	55.55%	8.60%	6.67	0.34	139	122	115	129

Table 3

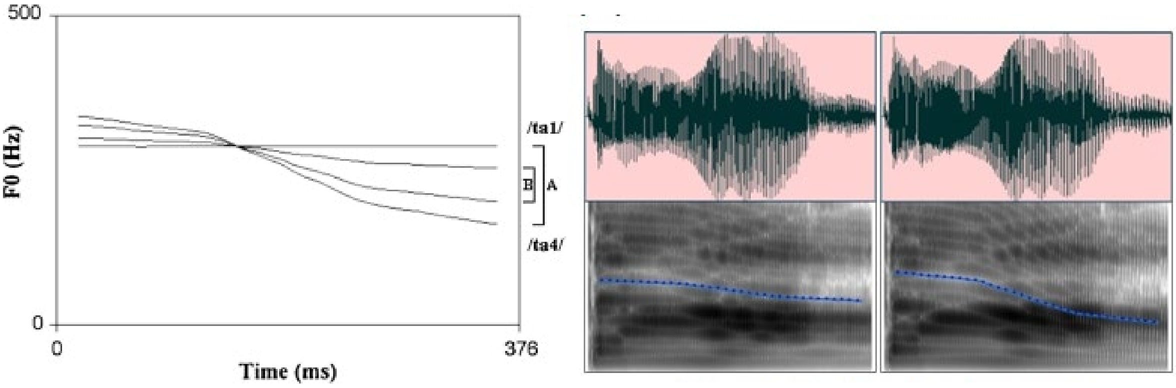
Model Summary of Hierarchical Multiple Regression for PPVT Scores.

Outcome Variable: PPVT scores (*N* = 16)					
Step	***B (SE B)***	***β***	***t***	**R^2 (Adjusted R^2)**	**ΔR^2**
Step 1				.01 (-.07)	.01
Age	-1.75 (5.99)	-.08	0.29		
Step 2				.39 (.29)*	.38*
Age	-0.41 (4.90)	-.02	0.08		
Non-native word learning abilities	77.35 (27.22)	.62	2.84*		
Step 3				.39 (.23)	.00
Age	-0.42 (5.11)	-.02	0.08		
Non-native word learning abilities	83.14 (85.02)	.67	0.98		
Age x Non-native word learning abilities	-4.29 (59.35)	-.05	-0.07		

Note. $^*p < .05$

Figure 1

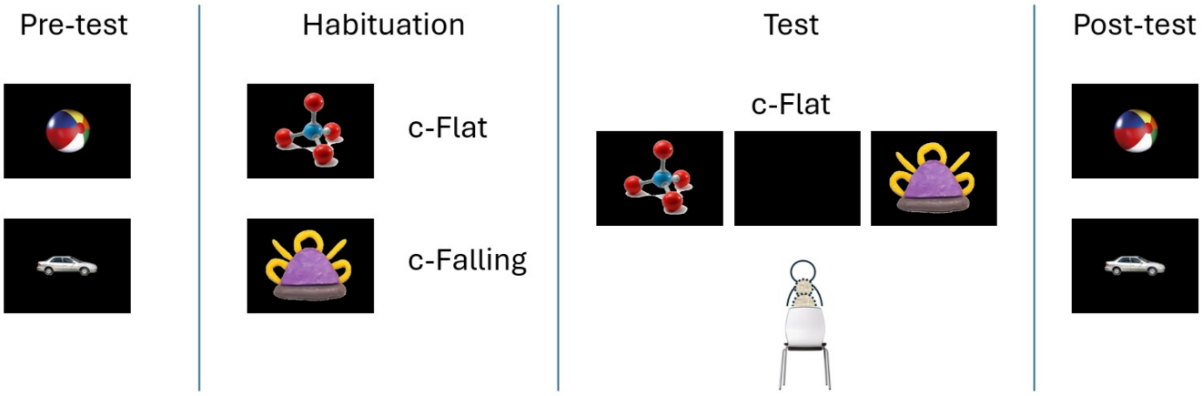
The Pitch Contours (Left), Oscillograms and Spectrograms (Right) of the Auditory Stimuli.



Note. Sources from Liu & Kager (2014; 2017, left) and adapted from Liu & Kager (2017). In Figure 1B: x-axis: duration; y-axis: amplitude.

Figure 2

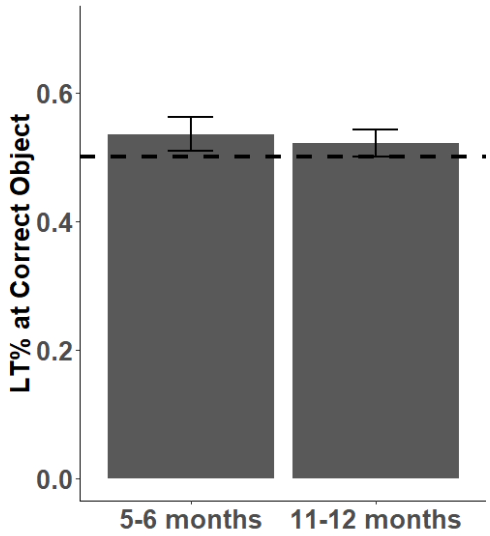
An example of stimuli and experimental setup



Note. (a) The current figure provides an example. The sound-object associations and the side on which objects appear were counterbalanced rather than fixed. (b) The illustration in the Test phase shows the experimental setup. Infants sat on their parents' laps facing three screens at the front. Visual presentations at other phases also showed up on side screens.

Figure

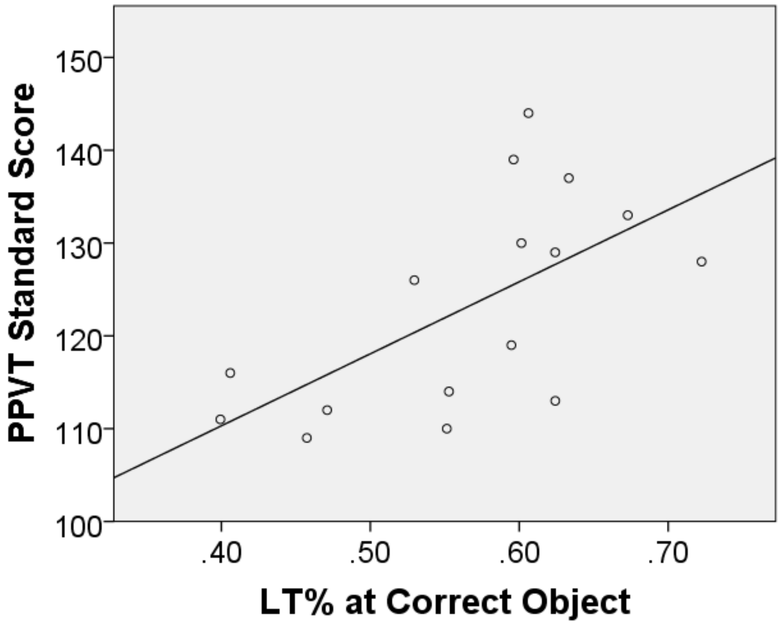
Mean percentage of looking at the correct object across two age groups



Note. No statistical difference was observed between the two age groups. Error bars = ±1 SE.

Figure 4

PPVT standard scores correlate with infants' associative word learning task performances



Note. y = 77.57x +79.28; R-square = 0.387.

Figure Captions

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