

WORD LEARNING IN CHILDREN WHO ARE DEAF OR HARD OF HEARING

by

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APPROVAL

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Thesis approved:



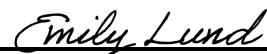
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Introduction

Although amplification technology for children who are deaf and hard of hearing (DHH) has improved in recent years, the issues of inconsistent access to sound and degraded auditory signals put children who are DHH at risk for developing problems with spoken language and/or listening skills (Klein et al., 2022). Children who are DHH can struggle with word learning, and consequently, the development of vocabulary comparable to peers with typical hearing, possibly caused by speech perception deficits and by prior auditory deprivation (e.g., Lund, 2016). Even when a child has a well-fit hearing aid or cochlear implant and received access to sound at an early age, listening conditions are still not ideal in the real world, and we see that children who are DHH may acquire words differently than children with typical hearing (Klein et al., 2022). That is, children who are DHH may find it more difficult to learn words that are similar (lexically dense) than words that are contrastive (lexically sparse; Kirk et al., 1995). Additionally, children who are DHH struggle with development of other domains of language, such as morphosyntax (Werfel et al., 2018). Difficulties with syntax could contribute to difficulties learning individual words, because word learning in real life rarely involves hearing words in isolation. The purpose of this study is to explore the effects of word density and syntax on word learning in children who are DHH.

Word learning may be defined as the cognitive process used to acquire new vocabulary. Though evidence of word learning appears at a young age, it requires many linguistic and nonlinguistic cognitive steps (Lund, 2020). Through repeated exposure and practiced usage, children build a comprehensive semantic representation of the words in their lexicon. By adulthood, a person with typical hearing will have learned around 20,000 word forms (Brysaert et al., 2016). However, for those who are DHH, the ability to perceive and then to learn words is

negatively impacted. In a recent study, children who were DHH, both with hearing aids and cochlear implants, exhibited reduced lexical access and competition while identifying spoken words when compared to children without hearing loss. More specifically, delays in lexical access creates a delay in spreading semantic activation which impacts children who are DHH in their ability to recognize new words (Klein et al., 2022). Research studies have also consistently shown a pattern of less robust word learning in children who are DHH. In a 2017 study by Lund and Scheule, children with cochlear implants learned fewer words than their chronologically age matched, typically hearing peers (Lund & Scheule et al., 2017).

The root of the deficit in word-learning for children who are DHH begins with their diagnosis: their ability to hear sounds is limited. This deficit then manifests in children who are DHH in difficulty learning new words when compared to children with typical hearing. Characteristics of words themselves likely contribute to learning outcomes. In a 1995 study by Kirk and colleagues, the effects of lexical characteristics on spoken word recognition were investigated in children who used a multichannel cochlear implant. The authors found that children with multichannel cochlear implants identified high frequency words with few neighbors and low density (words that occur often and do not sound similar to many other words) more easily than low frequency words and high density (words that do not occur often and sound similar to many other words; Kirk et al., 1995). This disparity may indicate that children who are DHH are more likely to build low density lexicons to avoid collapsing words at the phoneme level. Lund (2019) confirmed, in a study of words that children already knew, that children who wore cochlear implants knew fewer high-density words than children with typical hearing. Knowing different words, relative to lexical density, could lead to other long-term difficulties such as the development of phonological awareness (Lund, 2020).

Difficulties with hearing can also produce difficulties learning other domains of language (beyond semantics), such as syntax. Complex syntax is defined as utterances that contain more than one verb phrase (Barako Arndt & Schuele, 2013). In children with typical hearing and typical language, complex syntax development begins before 3 years of age. The development of complex syntax begins when children begin to combine words. (Bloom & Capatides, 1987; Bloom et al., 1984; Diessel, 2004; Limber, 1973). Diessel reports findings that show reduced infinitives, infinitival complement clauses, participle complement clauses, and coordinate clauses are amongst the earliest forms of complex syntax to develop. These complex forms (or constructions) act as a foundation for later forms like propositional complements and relative clauses (Diessel, 2004).

For children who are DHH, acquisition of complex syntax appears to be delayed. Previous studies indicate that children who are DHH produce shorter utterances, as measured by MLU, than their peers with typical hearing (Koehlinger et al., 2013; Werfel, 2018). With a reduced MLU, one could conclude that children who are DHH will struggle to produce long enough phrases to include complex syntax. Measures of early-developing (but not exclusively complex) syntax find that children who are DHH exhibit weaknesses in syntax compared to their age-matched peers with typical hearing (Moeller, 2010). More recently, Werfel and colleagues found that children who are DHH exhibit difficulty acquiring complex syntax compared to age-matched children without hearing loss (Werfel et al., 2021) and used some forms like relative clauses less often than children with typical hearing matched for MLU.

Understanding of complex syntax is also likely to affect word learning. When children learn new words, they typically learn those words from the world around them (and in sentences) rather than via direct instruction (Bloom, 2001). If children who are DHH exhibit delays in

complex syntax production (Werfel et al., 2021), then they may also be delayed in understanding complex syntax. If it takes substantial cognitive effort to understand words in complex sentences, then we might expect children who are DHH to learn fewer words from complex sentences than from simple sentences (Sweller, Ayres, & Kalyuga, 2011).

Syntax and word density influence the task of word learning for children DHH. Our study will systematically explore how target word density and syntax of carrier sentences influences learning in children who are DHH as compared to children with typical hearing. Although other studies have evaluated how children who are DHH understand words, recognizing how these linguistic characteristics influence learning is a first step towards building a model of word learning that includes internal (child-specific) and external (environmental) characteristics. Additionally, knowing which words are easier to learn, and in what carrier sentences, may help us to develop effective word learning interventions. We predicted that performance on word learning tasks will be improved in more simple syntax contexts and with words with lower densities, and that children who are DHH would learn fewer words regardless of condition than children with typical hearing. The following questions guided this study:

1. Do children with typical hearing learn more words across all conditions than children who are DHH?
2. Do children who are DHH learn more low-density words than high density words and is there an interaction between group and density?
3. Do children who are DHH learn more words that are embedded in simple syntax than words embedded in complex syntax and is there an interaction between group and syntax type?

4. Is there an interaction between neighborhood density and syntax type, and does that interaction vary by group?

Method

Participants:

This study included 37 participants with typical hearing, hearing aids, or cochlear implants, aged 86-133 months (mean 100.38 months). Groups include 10 children with typical hearing, 16 children with hearing aids, 9 with cochlear implants, and 2 with a combination hearing aid and cochlear implant, who were included in the cochlear implant group. All participants were recruited from the larger longitudinal Emergent Language and Literacy Acquisition (ELLA) study (NIH/NIDCD to PIs Werfel and Lund; e.g., Lund, Brock & Werfel, 2021). Additionally, all participants must not have had any additional disabilities. The ELLA study seeks to investigate the acquisition of language and literacy in children who are DHH.

Table 1. Study group characteristics

Criteria	TH	HA	CI
Age in months	<i>M:</i> 100.6 94 - 107 <i>SD:</i> 4.32	<i>M:</i> 102.4 86 - 133 <i>SD:</i> 12.75	<i>M:</i> 97.2 89 - 106 <i>SD:</i> 4.73
Sex (M:F)	4:6	10:6	5:6
EOWPVT	<i>M:</i> 116.30 98 – 140	<i>M:</i> 106.13 83 – 135	<i>M:</i> 96.18 59-127
PPVT	<i>M:</i> 114.70 94 – 149	<i>M:</i> 106.28 81 – 135	<i>M:</i> 95.91 66 – 126

Procedures

Word learning task. The word-learning task required participants to complete two computer-based, self-paced storybooks. Storybooks were presented on PowerPoint with audio used to tell the story to the participant. One storybook contained pseudowords that were consonant-vowel-consonant (CVC), high-density words (in the highest quartile of child corpus density) with mid-range phonotactic probability. The other storybook contained pseudowords that were CVC, low-density words (in the lowest quartile for child corpus density) based on a corpus generated by Storkel & Lee (2013). Each storybook incorporated 10 words repeated 6 times each. Half of the words were presented in simple sentences and half of the words were presented in sentences with complex syntax (balanced for word density presentation).

All participants were tested individually in a quiet room with the first author or one of two volunteers for the ELLA camp. For all purposes, instructions and details pertaining to the study were administered in English. All administrations used a scripted protocol to relay instructions (see Appendix A). Directions detailed instructions to participants and allowed time for clarifying questions from participants (Ex: “*You are going to listen to the first book ... You may pause the book at any time by pressing the three dots in the lower left corner and then pressing “pause.” Do you understand?*”). After completing both storybooks, participants were tested to determine learning of nonsense words. Flashcards were used to present the image representing the pseudoword word from the story and elicit naming by the participant. Participants completed the high-density storybook first with immediate recall tested after completion. Next, participants completed the low-density storybook with immediate recall of low-density words tested after completion. Then, the administrator returned to the high-density storybook to test for delayed recall. Participants were given a short break to ensure similar timing

for delayed recall before being tested for low-density delayed recall. All responses were recorded by written record (in international phonetic alphabet) and transcribed for data analysis.

Data Analysis

To answer the primary research questions, repeated measures analysis of variance calculations were conducted. The dependent variable for this analysis was number of words learned, and density and sentence complexity of the learning contexts were included as within-subjects independent variables, and group membership was included as a between-subjects dependent variable. Follow-up linear contrasts for main effects included a Bonferroni correction for multiple contrasts.

Results

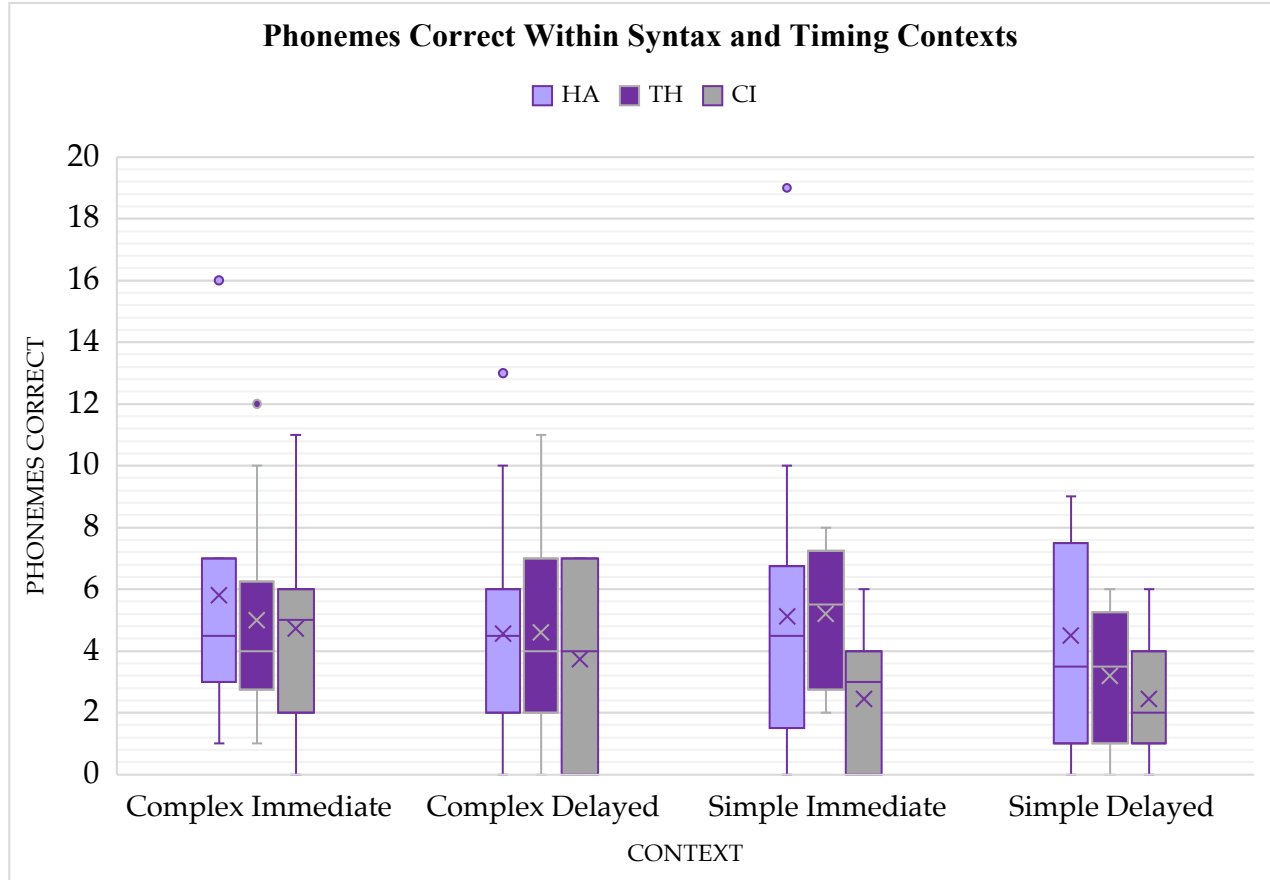
Initial analysis with whole word learning indicated that few entire phonological representations were built by children across groups, that is, few participants demonstrated accurate recall of complete words with accurate phonemes in the initial, medial, and final position. To capture partial learning and a greater variability, data was reported based on number of phonemes correct (with accurate initial, medial, and final positions). Visual analysis of the data also revealed one outlier participant: one participant with hearing aids learned nearly all of the words in the task. For purposes of analysis, the consistent outlier from the HA group was excluded.

The first research question asked whether children with typical hearing learn more words across all conditions than children who are DHH. Overall, we found no main effect of group on total phonemes learned ($F(2,33) = .79, p = .46$) but did see a main effect of time ($F(1,33) = 9.45, p = .004$). All children recalled fewer words after a 5-minute delay.

The second research question asked if children who are DHH learn more low-density words than high density words and is there an interaction between group and density? We found no main effect of group or density, but there was an interaction effect of density x group ($F(2, 33) = 6.54, p = .004$). Children with CI learned more high density than low density words, whereas children with TH learned more low than high density words.

The third research question examined if children who are DHH learn more words that are embedded in simple syntax than words embedded in complex syntax and if there an interaction between group and syntax type. Children learned more words in complex syntax than in simple syntax ($F(1, 33) = 4.31, p = .046$). More specifically, all children learned more high-density words in complex syntax rather than in simple syntax. The inverse was true for low-density words for the HA and TH group.

Figure 1 reflects the relationship between syntax type and delayed/immediate recall for all participant groups. There was no main effect of group or significant interaction effects; however, there was a main effect of syntax type ($F(1, 33) = 4.31, p = .046$). Children learned more words in complex syntax than in simple syntax.

Figure 1. Syntax and Recall Timing

Time x density x group: $F(2, 33) = 2.62, p = .08$

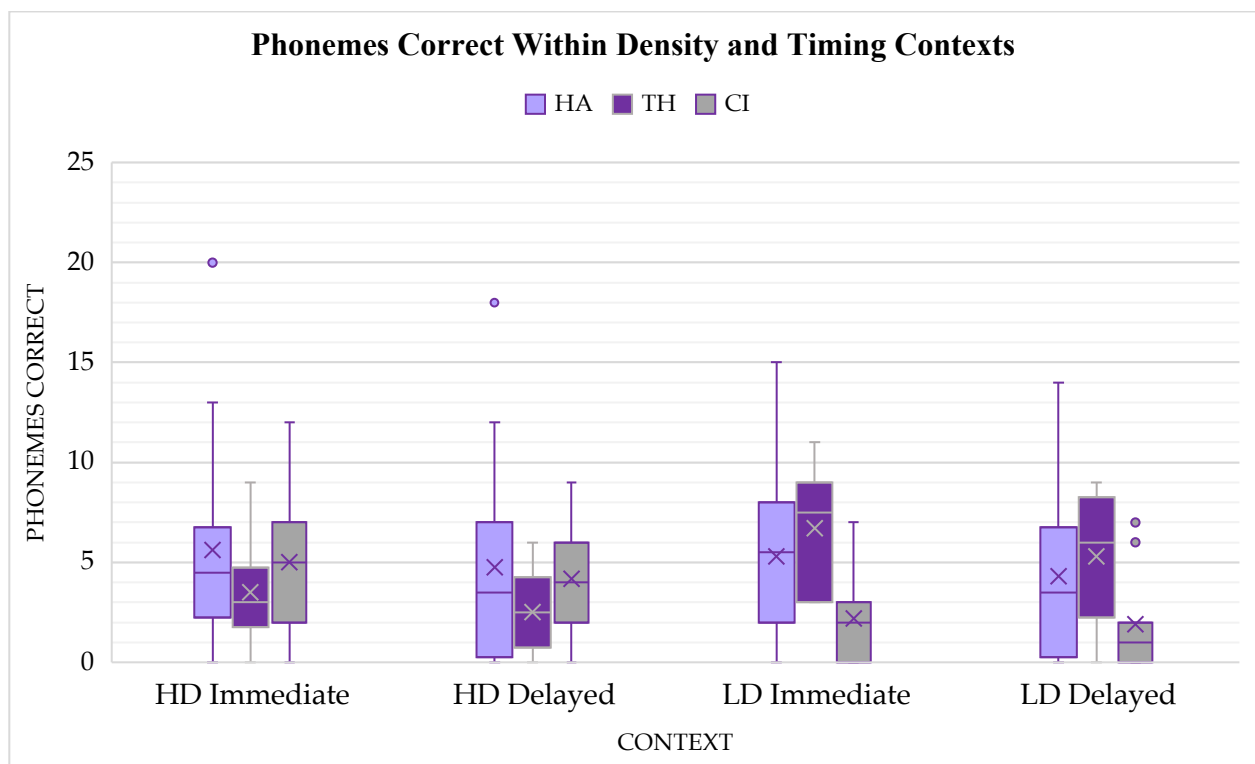
Table 2. Group and Condition Mean and Standard Deviation

Group	Condition	Mean	Standard Deviation
HA	Complex Immediate	5.8125	4.304
	Complex Delayed	4.5624	3.499
	Simple Immediate	5.125	4.567
	Simple Delayed	4.5	4.783
TA	Complex Immediate	5	3.256
	Complex Delayed	4.6	2.973
	Simple Immediate	5.2	2.135
	Simple Delayed	3.2	2.04
CI	Complex Immediate	4.727	3.25
	Complex Delayed	3.727	2.7
	Simple Immediate	2.455	1.827
	Simple Delayed	2.455	1.971

Figure 2 demonstrates data within the context of density and timing (immediate/delayed).

There was no main effect of group or density, but there was an interaction effect of density x group ($F(2, 33) = 6.54, p = .004$). Children with CI learned more high density than low density words, whereas children with TH learned more low than high density words.

Figure 2. Density and Recall Timing

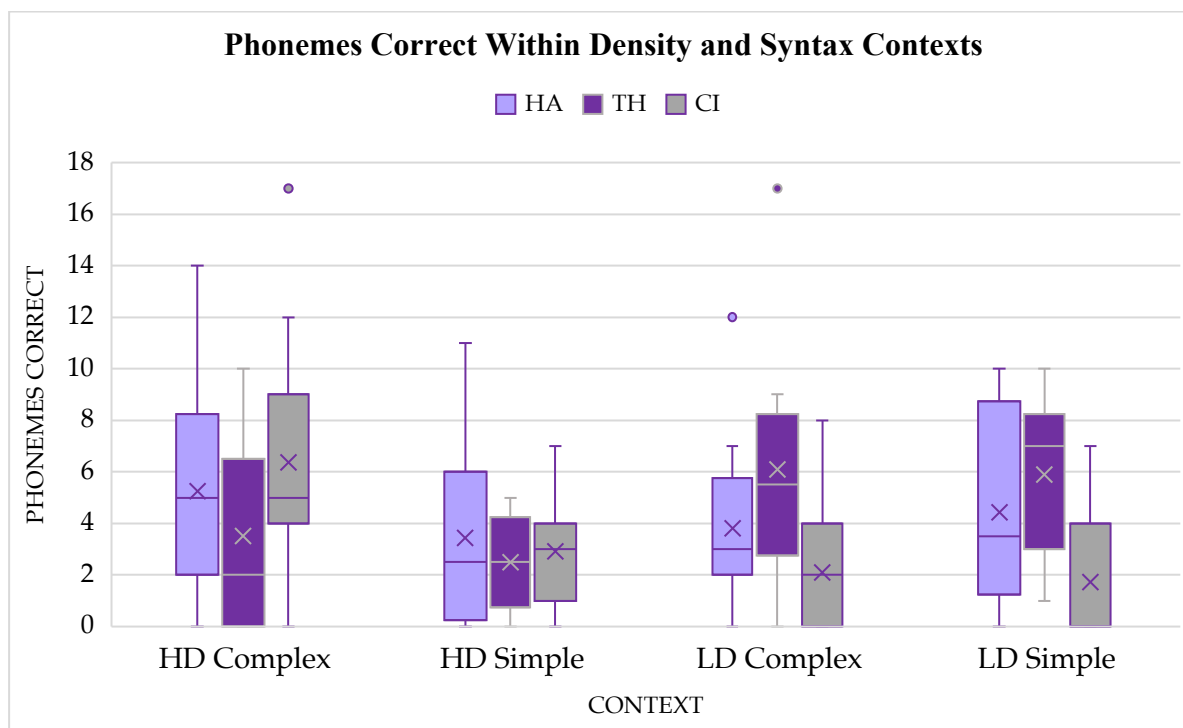


Density x Group: ($F(2, 33) = 6.54, p = .004$)

Table 3. Group and Condition Mean and Standard Deviation

Group	Condition	Mean	Standard Deviation
HA	HD Immediate	5.625	5.016
	HD Delayed	4.75	4.922
	LD Immediate	5.313	4.129
	LD Delayed	4.3125	4.024
TA	HD Immediate	3.5	2.579
	HD Delayed	2.5	1.962
	LD Immediate	6.7	2.722
	LD Delayed	5.3	3.164
CI	HD Immediate	5	3.568
	HD Delayed	4.182	2.691
	LD Immediate	2.182	2.124
	LD Delayed	1.909	2.314

Figure 3 shows data related to the fourth research question: group data by density and syntax type. Repeated measures analysis of variance revealed an interaction effect between density and complexity ($F(1,33) = 6.09, p = .019$) but no interaction between density, complexity, or group membership ($F(2, 33) = .622, p = .543$). Results show that, regardless of hearing status, all children learned more high-density words in complex syntax rather than in simple syntax. The inverse was true for low-density words for the HA and TH group relative to overall means, but the three-way interaction was not significant.

Figure 3. Density and Syntax*Table 4. Group and Condition Mean and Standard Deviation*

Group	Condition	Mean	Standard Deviation
HA	HD Complex	5.25	3.662
	HD Simple	3.438	3.24
	LD Complex	3.813	2.984
	LD Simple	4.438	3.535
TA	HD Complex	3.5	3.384
	HD Simple	2.5	1.857
	LD Complex	6.1	4.482
	LD Simple	5.9	2.948
CI	HD Complex	6.364	4.753
	HD Simple	2.909	2.234
	LD Complex	2.091	2.353
	LD Simple	1.727	2.998

Discussion

Extant literature indicates that children who are DHH and learning spoken language tend to perform worse on measures of language and literacy than their same-age peers with typical hearing (Lund, 2016; Werfel et al., 2018). This investigation explored how hearing loss status interacts with word learning contexts (neighborhood density of words and complexity of sentences) to influence word learning. On average in this study, children recalled 1-2 words from one reading of a self-paced storybook. As expected, children recalled fewer words (0-1) after a 5-minute delay as compared to an immediate assessment of learning.

Contrary to our prediction, children with CI learned more high than low density words, whereas children with TH learned more low than high density words. Children with HA learned roughly equal numbers of words across both types. Children with TH and HA tended to have higher vocabulary knowledge overall than children with CI. Therefore, it is possible that these groups were better equipped to learn low density words (which are traditionally more difficult to learn). It is possible that children with TH are proficient enough at word learning that they don't require assist from word density, or that they are drawn to learning words that were traditionally harder to learn. This type of learning pattern may explain why children with CI are likely to know words with different lexical characteristics than children with TH (Lund, 2019). By sorting lexicons based on phonemic similarity, children who are DHH may be able to learn words more efficiently. This difference positively impacts children who are DHH because high-density words support engagement and configuration due to their similarities to words already present in a child's lexicon. Previous studies indicate that children with CI know fewer high-density words long-term suggesting that the issue may be with retention rather than immediate learning (Lund, 2019).

Furthermore, all children learned more words in the complex syntax condition than in the simple syntax condition. It is possible that additional semantic content in sentences is actually helpful for word learning with nouns, rather than confusing - as some may assume. As previously stated, complex syntax development begins before 3 years of age. Foundational syntactic skills are crucial to later academic success with grammatical forms (Diessel, 2004). Children who are DHH might be presented with well-intentioned, yet unhelpful simplified forms of speech from others. In alignment with the previous discussion about children with CI, perhaps retention of words is impacted by assumptive expectations that hinder children's ability to retain words.

This study had several limitations due to the nature of study population. Chiefly, children learn new words from the world around them in varying applications rather than through a single reading of a storybook (Bloom, 2001). While this study did lack naturalistic opportunities to learn words, methods were consistent with other word learning studies. As with many research studies, the majority of participants in this study were white from middle to upper middle-class socioeconomic background. As such, included participants have a history of appropriate care and intervention, potentially skewing results to inaccurately represent those from more diverse backgrounds. Additionally, though measures were taken to ensure identical exposure to each participant, some participants received more than 6 (but no more than 8) exposures to a single nonsense word due to inference in video playback. The data from said participants was independently reviewed to ensure there was no skewed or outlying performance as a result of this interference. Standardization would also have been strengthened if the rate of speech was more closely monitored to examine if children who are DHH benefit from a slowed rate of speech. Other limitations may have included the potential for ceiling or floor effects in the

measures used and the reliance of self-report by those collecting data. Finally, some participants indicated clear disinterest in the study (potentially caused by fatigue from other testing completed during the same day) and demonstrated a lack of focus during the study which may have also negatively impacted results.

Limitations presented in this study may be rectified in a future experimental study that would allow for a standardized storybook with monitored rate of speech. Previous studies have suggested that individuals who are DHH benefit from a slower rate of speech (Winn and Teece, 2021). Though this study implemented an intentionally slowed rate of speech, using specific measurements to ensure consistent pace would eliminate potentially confounding variable.

Additionally, using a more diverse group of participants would allow results to be more appropriate for generalization. More specifically, other studies may find significant differences between racial and ethnic groups. This would be clinically significant for the application of intervention through culturally competent care. Future studies may also consider the role of auditory memory in analysis. For example, how might findings be impacted if children were to hear words versus read them. It is possible that the additional visual cue paired with an auditory one may impact recall in both immediate and delayed contexts. Finally, future studies may investigate how the presence and/or lack of a naturalistic setting contributes to these findings.

With this information, clinician and speech-language pathologists may be better prepared to provide intervention for children who are DHH. Through the combination of evidence-based practice and clinical expertise, we may close the gap present between children who are DHH and their typically hearing peers.

Conclusion

This study demonstrates that children, regardless of hearing status, recall fewer words after a 5- minute delay. Additionally, children learned more words in complex syntax than in simple syntax. Children with CI learned more high than low density words, whereas children with TH learned more low than high density words. Children with HA learned roughly equal numbers of words across both types. This research presents clinically relevant information regarding how professionals may approach teaching new words to children who are DHH. Through improved intervention, speech-language pathologists may help overcome the delay exhibited by children who are DHH.

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APPENDIX A

Protocol for Administration

**TEXAS CHRISTIAN UNIVERSITY (TCU) - HARRIS COLLEGE OF NURSING AND
HEALTH SCIENCES**

ADMINISTRATION OF WORD LEARNING PROJECT PROTOCOL

Student Name: Lisette Trevino

Degree Program: COSD

Faculty Project Advisor(s) Name(s): Emily Lund, Ph.D, CCC-SLP

Project Title: Word Learning in Children with Hearing Loss

The following steps outline the procedure for the Word Learning in Children with Hearing Loss study.

PART 1: HIGH DENSITY STORYBOOK

1. Using an IPAD, present the high density storybook to the participant.

“Today, you are going to listen to two storybooks. You will use this (gesture to IPAD) to listen to them.”

2. Explain the participant may start/pause the story book. However, the participant must allow the audio to fully play on each page.

“You are going to listen to the first book. This book will have some words that are new to you. Be sure to listen to each page. You may pause the book at any time by pressing the three dots in the lower left corner and then pressing “pause.” Do you understand?”

3. Once the storybook is complete, move towards immediate recall testing. Using flashcards 1-10, present the image of each animal from the high density storybook. Ask the participant to provide the animal’s name. For each response, transcribe the participant’s answer in IPA.

“Now, I want you to name the animals you saw in the book. If you don’t know it, just try your best. Ready?”

4. Once immediate recall testing is complete, move towards the low-density storybook. Keep the flashcards for high density words (cards 1-10) for delayed recall testing.

PART 2: LOW DENSITY STORYBOOK

1. Using an IPAD, present the low density storybook to the participant.

“Now, you are going to listen to another storybook. You will use this (gesture to IPAD) to listen to it.”

2. Explain the participant may start/pause the story book. However, the participant must allow the audio to fully play on each page.

“You are going to listen to the second book. This book will have some words that are new to you. Be sure to listen to each page. You may pause the book at any time by pressing the three dots in the lower left corner and then pressing “pause.” Do you understand?”

3. Once the storybook is complete, move towards immediate recall testing. Using flashcards 11-20, present the image of each animal from the low density storybook. Ask the participant to provide the animal’s name. For each response, transcribe the participant’s answer in IPA.

“Now, I want you to name the animals you saw in the book. If you don’t know it, just try your best. Ready?”

PART 3: DELAYED RECALL TESTING

1. After completing both storybooks and immediate recall testing for both high and low density words, move towards delayed recall testing.
2. Return to cards 1-10 to test for delayed recall of high density words. Using flashcards 1-10, present the image of each animal from the high density storybook. Ask the participant to provide the animal’s name. For each response, transcribe the participant’s answer in IPA.

“Next, I want you to tell me the names of these animals. You have already seen them before, but I want to see how many you still remember. Ready?”

3. Allow the participant a short play break using toys of interest.
4. Return to cards 11-20 to test for delayed recall of low density words. Using flashcards 11-20, present the image of each animal from the low density storybook. Ask the participant to provide the animal’s name. For each response, transcribe the participant’s answer in IPA.

“Next, I want you to tell me the names of these animals. You have already seen them before, but I want to see how many you still remember. Ready?”

PARTICIPANT ID: _____

HIGH DENSITY IMMEDIATE RECALL RECORD FORM		
ASSIGNED NUMBER	TARGET NAME	PROVIDED RESPONSE (IPA)
1	haob	
2	wub	
3	dop	
4	jaot	
5	von	
6	gɛp	
7	kaŋ	
8	vim	
9	giŋ	
10	fɜf	

LOW DENSITY IMMEDIATE RECALL RECORD FORM		
ASSIGNED NUMBER	TARGET NAME	PROVIDED RESPONSE (IPA)
11	dʒud	
12	tug	
13	waʊd	
14	yid	
15	duŋ	
16	hɜp	
17	nim	
18	gʌf	
19	taɪg	
20	tiv	

HIGH DENSITY DELAYED RECALL RECORD FORM		
ASSIGNED NUMBER	TARGET NAME	PROVIDED RESPONSE (IPA)
1	haob	
2	wub	
3	dop	
4	jaot	
5	von	
6	gɛp	
7	kaŋ	
8	vim	
9	giŋ	
10	fɜf	

LOW DENSITY DELAYED RECALL RECORD FORM		
ASSIGNED NUMBER	TARGET NAME	PROVIDED RESPONSE (IPA)
11	dʒud	
12	tug	
13	waʊd	
14	yid	
15	duŋ	
16	hɜp	
17	nim	
18	gʌf	
19	taɪg	
20	tiv	

ABSTRACT

WORD LEARNING IN CHILDREN WHO ARE DEAF OR HARD OF HEARING

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Children who are deaf or hard of hearing (DHH) and learning spoken language struggle with crucial communication skills (e.g., Lund, 2016). This study investigated the impact of syntax, word density, and timed recall on overall word learning.

Participants had either typical hearing (TH), hearing aids (HA), or a cochlear implant (CI). Participants were asked to participate in the reading of two, pre-recorded storybooks with high-density and low-density words respectively prior to demonstrating immediate and delayed expressive recall.

Children recalled fewer words after a 5-minute delay. Children learned more words in complex syntax than in simple syntax. Children with CI learned more high than low density words, whereas children with TH learned more low than high density words. Children with HA learned roughly equal numbers of words across both types. This research presents clinically relevant information regarding how professionals may approach teaching new words to children who are DHH.