LONGITUDINAL STUDY OF LEXICAL-SEMANTIC ORGANIZATION AS MEASURED BY REPEATED WORD ASSOCIATIONS IN CHILDREN WHO ARE DEAF AND HARD OF HEARING

by

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Abstract

Lexical-semantic organization refers to the system of relationships between words and concepts that a child has in their vocabulary. Previous research shows that children who are deaf and hard of hearing (DHH) who use spoken language may have differences in their lexical-semantic organization systems as compared to their peers with typical hearing (TH). However, characterizations of the longitudinal development of lexical-semantic organization systems for children who are DHH compared to children with TH are unclear; the purpose of the present study is to investigate this development. The following research questions guided this paper: Between the ages of four and seven, do children who are DHH and children with TH differ in their growth in semantically-related responses? Between the ages of four and seven, do children who are DHH and children with TH differ in their growth in clang responses? Between the ages of four and seven, do children who are DHH and children with TH differ in their growth in taxonomically-related responses? Between the ages of four and seven, do children who are DHH and children with TH differ in their growth in paradigmatic responses? To answer these questions, results of the repeated word association task were analyzed. Results showed that both children who are DHH and children with TH increase their semantically-related responses over time, but children who are DHH respond, on average, with fewer semantically-related responses than their TH peers over the ages of four to seven. For clang responses, time predicts a decrease in responses for children who are DHH, but not for children with TH. No notable growth was found in the rate of taxonomic-related responses for neither group. Finally, time predicts an increase in paradigmatic responses for children who are DHH but not children with TH. Implications of the results are discussed.

Introduction

Research has demonstrated that children who are deaf and hard of hearing (DHH), including children with hearing aids and cochlear implants, have less developed expressive vocabularies than their typical hearing peers. Perhaps as a consequence of difficulties with expressive vocabulary, children who are DHH also struggle with organizing their vocabulary in the same way that their typical hearing peers do. Although Rush, Werfel, and Lund (2023) documented that children who are DHH may have deficits in their lexical-semantic organization systems, it is still unclear whether the organization systems for children who are DHH and children with typical hearing experience the same longitudinal development or if the development over time differs for each group. The purpose of the present study is to investigate the longitudinal maturation of the lexical-semantic organization systems of children who are DHH as compared to their typical hearing peers as measured by a repeated word association task. Specifically, the growth of semantically related responses, clang responses, paradigmatic responses, and taxonomic responses over time for children who are DHH and children with typical hearing will be analyzed.

Lexical-Semantic Organization and Measurement

Lexical-semantic organization is a part of the process of lexical engagement, the final stage of word learning that involves connecting new words to the words that a child already knows (Lund, 2020). The relationships between words and concepts that a child recognizes and develops makes up their lexical-semantic organization system or network. Sheng & McGregor (2010) describe lexical-semantic organization using a semantic network model, where words in a child's vocabulary are represented by nodes. Each node is connected to other semantically related nodes. In a well-developed semantic organization system, there are numerous links between different nodes (Sheng & McGregor, 2010). For example, using the word “dog” could activate words such as “bone”, “collar”, or “cat,” which would be represented as nodes connected to dog.

The repeated word association (RWA) task has been widely used to measure lexical-semantic organization (Sheng & McGregor, 2010). When a stimulus is presented, a node that represents that word in the semantic network is activated. This activation then spreads from one node to another as responses are given. Weaker connections from the stimulus node will lead to invalid responses or no responses. The RWA provides insightful information on the amount, type, and strength of relationships that a word has in a child’s lexicon (Sheng & McGregor, 2010). There are several types of responses that a child can provide during the RWA that provide information on the maturity of their lexical-semantic organization. Responses can be either semantically related or not semantically related to the target word. Responses may also be phonologically related to the target but not semantically related. These include responses that rhyme or alliterate with the stimulus. For those responses that are semantically related to the target, responses can either be classified as thematic or taxonomic. The number of responses from each of these categories reveals information about the maturity of a child’s lexical-semantic organization.

As a child with typical hearing develops their lexical-semantic organization system, they shift from having a high number of phonological relations to having more semantic relations (Cronin, 2002). Younger children are more likely to produce phonologically related responses than older children, as they have not yet shifted from a sound-based semantic organization system to a meaning-based one (Sheng & McGregor, 2010). As a meaning-based organization system is developed, a child’s lexical-semantic organization matures.

Next, shifting from using thematic relations to taxonomic relations is a shift that is representative of maturation of a child's lexical-semantic organization. Thematic relations are relationships that exist in the same theme or schema. For example: dog, bone, bark, fuzzy, and tail all would be classified as thematic relations. Taxonomic relations fit into categories. For example: dog, cat, and bear all fit into the same category. Taxonomic relations also include superordinate or subordinate categories. Dog fits into the superordinate category of animals, and labradoodle is a subordinate category of dogs. The thematic-taxonomic shift typically occurs in middle childhood for typically developing children and is usually accompanied by significant growth in the child's vocabulary (Sheng et al., 2006). Although the thematic-taxonomic shift does not occur until middle childhood, it has been discovered that children as young as three years of age can understand the meaning of taxonomic relations (Waxman & Gelman, 1986).

As children's lexical-semantic organization systems continue to mature, they shift from using syntagmatic responses to paradigmatic responses. Syntagmatic responses follow a different form class from that of the stimulus, and paradigmatic responses follow the same form class as the stimulus (Rush, Werfel, & Lund 2023). Syntagmatic responses usually are used by children first because they can originate from the concept of connected language (apple-eat). These associations can appear as early as a child can use two-word phrases (Cronin, 2002). Paradigmatic responses are more mature, because they typically provide information on categories or spectrums of word relationships (hot-cold or cat-dog). The presence of these responses represents the growing vocabulary and category knowledge that a child is acquiring. Typically, an increase in paradigmatic responses is accompanied by an increase in taxonomic relations (Lippman, 1971). Lippman stated that the paradigmatic-syntagmatic shift typically occurs for children between the ages of seven and eight.

Lexical-Semantic Organization in Children who are Deaf and Hard of Hearing

Hearing aids amplify sound through a microphone that is directed into the external ear canal (Martin & Clark, 2015). Hearing aids increase the amplification of sounds, but not necessarily the intelligibility of the sounds (Lesica, 2018). Furthermore, hearing aids can distort characteristics of sound (Davies, Holt & Demuth, 2022), which can make it difficult for listeners to understand nuanced words. Cochlear implants, another device used to address hearing loss, directly stimulate the auditory nerve through changing the acoustic signal into electrical impulses, which also enhances sound properties (Martin & Clark, 2015, Davies, Holt, & Demuth, 2022). Although both devices provide access to spoken language, this does not guarantee an increased ability to learn vocabulary due to their limitations.

Children who are deaf and hard of hearing (DHH) have lower expressive vocabularies than their typical hearing peers (Persson et al., 2022). This difference is likely due to interferences with word learning as a result of less-than-optimal auditory input due to their hearing status. Cochlear implants make remarkable differences in the hearing abilities of people with moderate to severe hearing loss (Tyler, 1991). Studies recommend early implantation (cochlear implants) or amplification (hearing aids) to take advantage of the potential benefit that devices can have on hearing; early implantation supports vocabulary development for deaf and hard of hearing children (Persson et al., 2022). Nonetheless, children with cochlear implants (CIs) will experience delayed vocabulary development even with early implantation of CIs due to the period when they were deprived of auditory input through spoken language (Lund, 2016).

A meta-analysis of studies on the vocabulary knowledge of children with CIs show that it is unlikely that these children would be able to catch up to their typical hearing (TH) peers (Lund, 2016). Other studies indicate that children who are DHH and learning spoken language may know different words than their peers with TH. Specifically, Lund & Dinsmoor (2016) state that the vocabulary deficit lies in the quantity of learned vocabulary words.

These deficits in vocabulary knowledge for DHH children could be a result of difficulties in the word learning process. Deaf and hard of hearing children could have breakdowns in any of the three stages of word learning: triggering, configuration, and engagement (Lund, 2020). There is evidence of long-term consequences resulting from these breakdowns, such as less words learned, different types of words learned (between TH and DHH children), and difficulties with reading and literacy skills (Lund, 2020). The development of lexical-semantic organization is a part of the engagement stage of word learning, which introduces the potential for less developed lexical-semantic organization systems among DHH children.

Studies show that lexical-semantic organization differs between children who are deaf and hard of hearing and children with typical hearing. First, children with CIs use fewer superordinate taxonomic labels when compared to their aged-matched typical hearing peers in a taxonomic naming task (Lund & Dinsmoor, 2016). These results suggest that DHH children have a less developed taxonomic organization system, which is the more mature system that develops after thematic organization. This finding aligns with research that concludes that DHH children are less likely to use taxonomic organization than typical hearing peers (Marschark et al., 2004).

Rush and colleagues attempted to compare the syntagmatic-paradigmatic shift between DHH and TH children in their study but did not capture the shift in the age range that was studied. This shift is expected during “middle childhood” for children with typical hearing, and existing data on when it is observed in children who are deaf and hard of hearing is lacking. Further study with the RWA is required to evaluate the syntagmatic-paradigmatic shift in DHH children.

These differences in the lexical-semantic organization systems of DHH and typical hearing children could be reflected in the results of studies of word retrieval. In a study of semantic organization of children between the ages of seven and ten, Kenett and colleagues demonstrated that children with TH have a more robust and complex vocabulary system than DHH peers as shown by their performance on a timed animal verbal fluency task. These results indicate that children with CIs have less complex semantic networks than their TH peers and have difficulties activating different words in those networks (Kenett et al., 2013). Correspondingly, results from a study administering a word association task and analogy task on deaf and hearing students showed that DHH children retrieve words from their mental lexicons differently than their TH peers (Marschark et al., 2004), which could explain the observed differences in their word-retrieval strategies.

Although the syntagmatic to paradigmatic and thematic to taxonomic shift has been theorized and demonstrated in children with typical hearing (Cronin, 2002 & Lippman, 1971), research yields inconclusive results for when these shifts occur for children who are deaf and hard of hearing. In a study that compared the lexical-semantic organization systems of children who are deaf and hard of hearing and using spoken language to their peers with typical hearing, there was no significant trend in the taxonomic response growth between children in kindergarten and a different group of children in first grade (Rush, Werfel, & Lund 2023). This means that the thematic-taxonomic shift within the repeated word association task was not yet captured within this age range, requiring further study of older children to determine when the shift occurs. In the same study, Rush and colleagues did not document a significant syntagmatic to paradigmatic shift within DHH children or TH children. This was partially attributed to the fact that there were no adjectives included in the stimulus list for the repeated word association task, and adjectives have been proven to elicit the most paradigmatic responses when compared to other parts of speech (Nelson, 1977). However, this may also relate to the age range studied, and that the study design was cross-sectional.

Although Rush and colleagues' (2023) study provided initial documentation of differences in lexical-semantic organization between children with TH and children who are DHH, its design was not ideal for tracking developmental progress. A cross-sectional design collects data from different groups of children at different ages. Because cross-sectional designs do not track the same children over time, they may miss developmental shifts. Longitudinal study of the lexical-semantic organization of children who are deaf and hard of hearing compared to their typical hearing peers through the repeated word association task can provide valuable information about the development of these group's lexical-semantic networks. Following the repeated word association task data for groups of children with hearing aids, cochlear implants, and typical hearing across a period of three years presents the potential that the expected shifts in maturity in lexical-semantic organization systems will be captured.

Relationships Between Lexical-Semantic Organization and Other Factors

The results from the repeated word association task can correlate with other language, literacy, and cognitive skills – thus, the development of lexical-semantic organization has implications for other skills. In a study that examined the impact that reading skill acquisition had on paradigmatic responses, it was found that the development of reading skills and the increase of paradigmatic responses are correlated as measured by a regression analysis (Cronin, 2002). Specifically, this increase was related to high word comprehension scores.

Clang responses, which either rhyme or alliterate with the stimulus word, are more frequent for younger children (Sheng & McGregor, 2010). At a younger age, phonological awareness skills are developing in children with typical hearing. Younger children could be relying on a sound-based lexical-semantic organization system, leading them to produce more clang responses. However, as children get older and develop a robust phonological awareness system separate from their vocabulary knowledge, they may shift towards a meaning-based lexical-semantic organization (Sheng & McGregor, 2010), as seen through more frequent semantically related responses.

It is also possible that there are links between maturity of lexical-semantic organization and a child's nonverbal cognitive skills. Taxonomic organization, which is the most mature level of organization, requires the most abstract cognitive skills to master (Di Giacomo et al., 2012, Lucariello, et al., 1992). On the contrary, children are able to rely on contextual knowledge to create thematic associations, requiring less cognitive ability. Although this idea supports the link between cognition and lexical-semantic organization maturity, it has been shown that word-learning and vocabulary development strategies mostly rely on language abilities, instead of cognitive skills (Lederberg, et al., 2000), which could refute the connection. Additionally, Lund & Dinsmoor (2016) attributed differences in taxonomic organization between DHH children and TH children to factors other than cognition. Thus, as a next step in a line of inquiry, longitudinal development of lexical-semantic organization should be explored. Understanding longitudinal development will help us then ask questions about how that development contributes to other linguistic and cognitive outcomes.

The purpose of the present study is to compare lexical-semantic organization in children with typical hearing, hearing aids, and cochlear implants over time. The following research questions guide this study:

1. Between the ages of four and seven, do children with CI, children with HA, and children with TH differ in their growth in semantically-related responses?
2. Between the ages of four and seven, do children with CI, children with HA, and children with TH differ in their growth in clang responses?
3. Between the ages of four and seven, do children with CI, children with HA, and children with TH differ in their growth in taxonomically-related responses?
4. Between the ages of four and seven, do children with CI, children with HA, and children with TH differ in their growth in paradigmatic responses?

Method

All procedures in this study were approved by the University of South Carolina Institutional Review Board as the IRB of record, as agreed by Texas Christian University.

Participants

Participants in this study are a part of the Early Literacy and Language Acquisition (ELLA) study, a larger longitudinal study of children who are deaf and hard of hearing and who use spoken language as their primary method of communication. A total of 48 children participated in the tasks analyzed for this present study of lexical-semantic organization. The participants include 22 children with typical hearing (TH) and 26 children who are DHH. Of the 26 DHH children, 13 use cochlear implants (CIs) and 13 use hearing aids (HAs). Although some of these participants also participated in the Rush, Lund & Werfel (2023) study, the current study includes new participants and new time points for all participants, allowing investigators to report on longitudinal growth within-subject. Each participant completed the task at least three times over the course of ages of five years, zero months (with a range of approximately three months) to the summer following completion of second grade. Tables with information on how many children completed the repeated word task at each time point are included below.

Group 1 included the children with typical hearing (CTH). Of the 22 children with typical hearing, 8 are males and 16 are females. Group 1 maternal education was, on average, 17.68 years, where 16 years indicates completion of an undergraduate degree (SD = 2.25).

Group 2 consisted of the DHH children who use cochlear implants or hearing aids (CCI and CHA, respectively). Of these 26 DHH children, 10 are females and 16 are males. Average maternal education for CCI was 16.85 years (SD = 1.57). The average age of the first implantation of a CI was 32.61 months (SD = 19.85). The severity of hearing loss for CCI ranged from severe to profound. Average length of maternal education for CHA is 16.54 years (SD = 3.33). The average age of first amplification through hearing aids was 12.04 months (SD = 12.96). The severity of hearing loss ranged from mild to severe-to-profound for CHA. Participant demographic information is summarized in Table 1.

Table 1. Group characteristics

Amplification group	Sex assigned at birth	Maternal education (years)	Age at first amplification (months)	Age at first implantation (months)	Degree of hearing loss
Typical Hearing (CTH)	Female = 14 Male = 8	*M* =17.68 SD = 2.25	Not applicable	Not applicable	Not applicable
Cochlear Implant (CCI)	Female = 6 Male = 7	*M* =16.85 *SD* = 1.57	*M* = 7.74 *SD* = 9.60	*M* = 32.61 *SD* = 19.85	Profound = 7 Severe to Profound = 4 Severe = 2
Hearing Aid (CHA)	Female = 4 Male = 9	*M* =16.54 *SD* = 3.33	*M* = 12.04 *SD* = 12.96	Not applicable	Severe to Profound = 1 Moderately Severe = 3 Moderate = 3 Mild to Moderate = 4 Mild = 1 Did not specify = 1

Table 2. Number of participants that completed the RWA at each time point

Amplification group	Time 3	Time 5	Grade 1	Grade 2
Typical Hearing (CTH)	18	15	14	17
Cochlear Implant (CCI)	11	8	11	9
Hearing Aid (CHA)	10	10	12	10

Data Collection

All assessments were completed in small rooms or areas for the evaluator to conduct all assessments in a quiet, individual setting with minimal distractions. Speech-language pathologists and trained graduate assistants administered all assessments, including the repeated word association task. The administering clinicians were trained to appropriately administer assessments by the primary investigators of the ELLA study. Additionally, a detailed instruction and protocol sheet for the repeated word association task was provided for the clinicians. The administration of the repeated word association task was recorded with video or audio to assess fidelity of task administration.

Test Stimuli

The primary investigators adapted a repeated word association task that was created by Sheng and McGregor (2010). The task included 24 stimulus words, including 12 verbs (*Count, Run, Sing, Read, Swim, Push, Squeeze, Eat, Hide, Cry, Kick, Yawn)* and 12 nouns (*Pillow, Spoon, Desk, Kite, Turtle, Broom, Zipper, Frog, Cow, Goat, Hat, Foot).* Each stimulus word was presented to the child three separate times within the same administration of the task. To begin the task, the clinician read instructions to produce a single word verbally as a response to the stimuli word. The instructions were read aloud as follows:

> *"We are going to play a word game. I'm going to say a word and I want you to tell me the first word that comes to mind after you hear my word. Let's practice. If I said the word 'mom', a word you can tell me is 'dad', 'family', 'brother', or 'sister'. If I say the word 'birthday', a word you can tell me is 'cake', 'candles', 'presents' or 'ice cream'. Now you try some. I am going to say the same word three times, so you will try to tell me a new word each time".*

To establish understanding of the task, the examiner gave the child an example of a stimulus word (moon) and possible responses that represented thematic (e.g., sky) and taxonomic (e.g., sun) relationships with the stimulus word. The clinician administered a practice set of words with "moon", "grass" and "cut", repeating each word three times inconsecutively to imitate the repeated environment of the task. If a participant repeated a previous response at any point during the task, the examiner reminded the child to think of a new word or say, “I don’t know”. The clinician waited 20 seconds after the presentation of a stimulus before marking the silence as an absence of response. The repeated word association task took approximately 30 minutes to complete. The examiners administered one of four forms (Form A, Form B, Form C, or Form D) to each child. All the forms contained the same 24 stimulus words in different presentation orders. Participants were given a new form of the task at each time point.

Data Analysis

A coding manual was developed and can be found in the appendix. This coding manual was modeled after Rush et al.’s (2023) code book, who based her code book on the work of Sheng and McGregor (2010) and Sheng et al (2006). Adaptations to the Rush et al. codebook were designed to clarify examples and non-examples to improve coding clarity. After the participants completed the administration of the repeated word association task, their responses were coded according to the manual for semantic relations to determine the maturity of their lexical-semantic organization skills. First, the response is classified as being semantically related (SR) or not semantically related (NSR). Not semantically related responses fall into one of three categories: clang responses, which relate to the stimulus phonetically (rhyming or alliterating) instead of semantically, errored responses, such as repetitions or inflections of the stimulus, or real words that are not semantically or phonologically related to the stimulus, or no response, including nonsense words, repetition of previous responses for that stimulus, or a complete absence of a verbal response. Semantically related responses fall into one of two categories: thematic or taxonomic. Thematic responses can be classified as function relations (e.g. read-book), descriptive (e.g. dog-furry), causal (e.g. yawn-tired), part-whole (e.g. turtle-shell), syntactic (e.g. stand-up), or location relations (e.g. swim-water). Taxonomic responses can be classified as superordinate (e.g. cat-animal), coordinate (e.g. cat-dog), or subordinate (e.g. cat-tabby). Finally, all semantically related responses are coded as either paradigmatic or syntagmatic. Paradigmatic responses are the same part of speech as the stimulus (e.g. stimulus and response are both nouns), and syntagmatic responses are different parts of speech than the stimulus (e.g. stimulus is a noun and response is a verb). The complete, detailed coding manual can be found in the appendix.

Coding Fidelity

To achieve reliable coding of the repeated word association task, responses were coded by two separate coders. Both coders then reviewed the codes together and came to an agreement on any codes that were different. Some of the repeated word association tasks were already coded once and these were checked by a second coder. All codes that were not agreed upon were discussed and rectified.

Results

This study explored how the development of lexical-semantic organization systems differs between children who are deaf and hard of hearing and children with typical hearing between the ages of four and seven.

To answer each of the research questions, two hierarchical linear modeling (multivariate growth curve models) were run: one for children who are DHH, and the second for children with typical hearing. For the purposes of this analysis, children with cochlear implants and children with hearing aids were combined into a single DHH group. The fixed effect for this model was age, and the model included a random intercept and random slope with an unstructured covariance matrix. There was no evidence of model assumption violations. This same model was run for four different dependent variables: semantically-related responses, clang responses, taxonomically-related responses, and paradigmatic responses.

The models for semantically-related responses are listed below in Table 4. Figure 1 represents the number of semantically-related responses over time for both children who are DHH and children with TH.

Table 3. Semantically-related responses of children with typical hearing and who are DHH

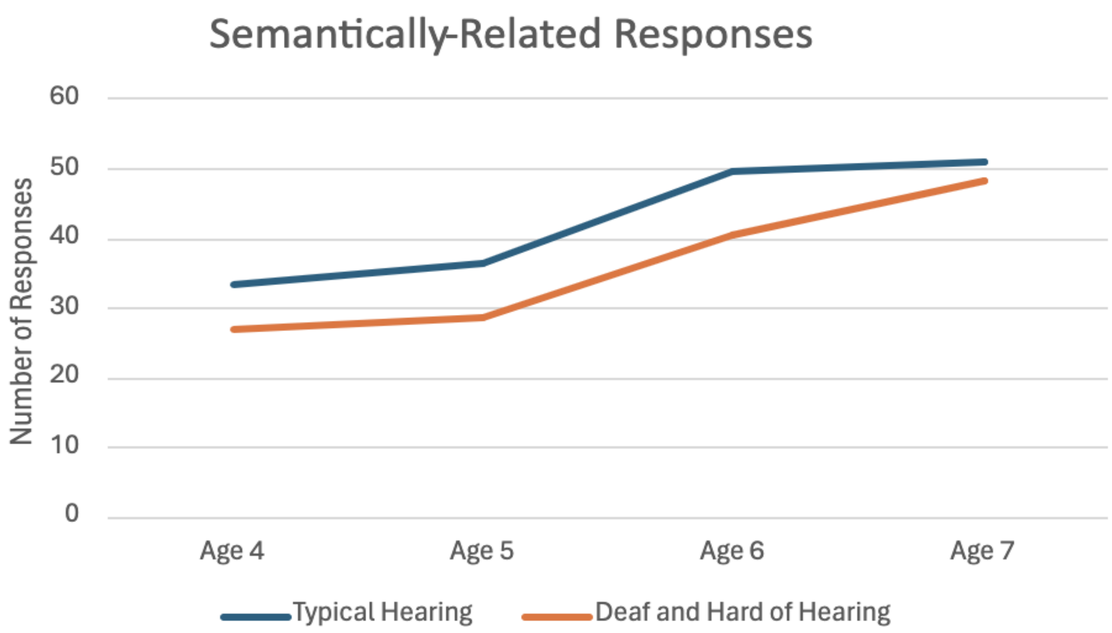
Typical Hearing

	Estimate	**SE**	***t***	***p***
Intercept	33.25	3.40	9.78	<.001
Time (Centered at age 4)	6.07	1.29	4.71	<.001

DHH

	Estimate	**SE**	***t***	***p***
Intercept	26.73	3.06	8.72	<.001
Time (Centered at age 4)	6.71	1.19	5.63	<.001

Figure 1.



At age four (where time is centered), the expected performance for children with TH is 33.25 semantically related responses and with each year increase, it is anticipated that children will gain an additional 6.07 semantically-related responses on average as represented by the coefficient term associated with age. The intercept performance of children who are DHH is 26.73 semantically-related responses at age four, as time was centered at this age in this model. With each year increase in age, children increased their semantically related responses by 6.71 responses on average as represented by the coefficient term associated with the Time variable.

The first research question asked if children who are DHH and children with TH differ in their growth in semantically-related responses between the ages of four and seven. Growth rates do not appear to differ (6.07 responses and 6.71 responses for groups each year). To consider between-group differences, to evaluate differences at beginning (age four) and ending (age seven) time points, an analysis of variance compared group performances. There were not significant group differences at age four ($F(1,38) = 1.32$, $p = .258$; TH $M = 33.50$, $SD = 19.04$;

DHH *M* = 26.95, *SD* = 16.56) or at age seven ($F(1,35) = .343$, $p = .56$, TH *M* = 51.12, *SD* = 16.31; DHH *M* = 48.42, *SD* = 11.08). Thus, both groups experience significant growth in semantically-related responses and descriptively, children who are DHH produce fewer semantically-related responses across timepoints, but those differences are not statistically significant in comparison to the TH group.

The models for clang responses are listed below in Table 5. Figure 2 represents the number of clang responses for both groups over time.

Table 4. Clang responses of children with typical hearing and who are DHH

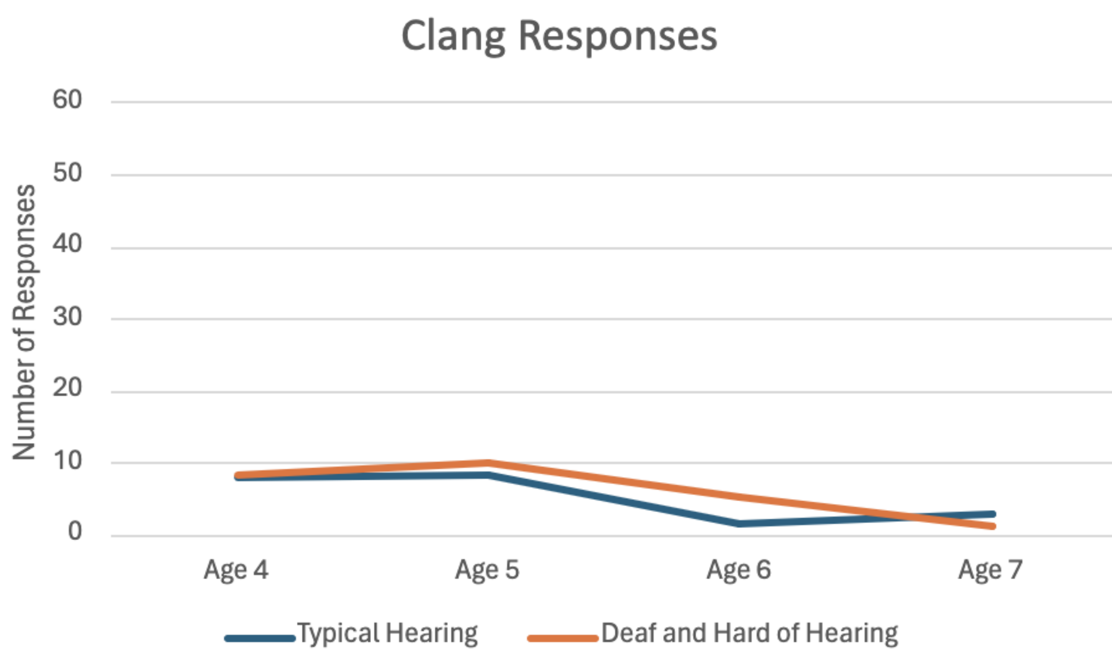
Typical hearing

	Estimate	**SE**	***t***	***p***
Intercept	8.34	2.66	3.14	.003
Time (Centered at age 4)	-1.97	1.26	-1.56	.125

DHH

	Estimate	**SE**	***t***	***p***
Intercept	9.71	2.35	4.13	<.001
Time (Centered at age 4)	-2.54	.99	-2.55	.013

Figure 2.



At age four (where time is centered), the expected performance for children with TH is 8.34 clang responses and with each year increase, it is anticipated that children will decrease by 1.97 clang responses on average as represented by the coefficient term associated with age. The intercept performance of children who are DHH is 9.71 clang responses at age four, as time was centered at this age in this model. With each year increase in age, children decreased responses by 2.54 responses on average as represented by the coefficient term associated with the Time variable.

The second research question asked if children who are DHH and children with TH differ in their growth in clang responses between the ages of four and seven. Growth rates was only significant for the DHH group in this model, indicating that children who are DHH are significantly decreasing in clang responses, but children in the TH are not. To consider overall between-group differences, to evaluate differences at beginning (age four) and ending (age seven) time points, an analysis of variance compared group performances. There were not significant group differences at age four (*F*(1,38) = .007, *p* = .933; TH *M* = 8.17, *SD* = 14.43; DHH *M* = 8.52, *SD* = 11.95) or at age seven (*F*(1,35) = .701, *p* = .41, TH *M* = 3.06, *SD* = 9.81; DHH *M* = 1.16, *SD* = 1.34). Overall, it appears children are eliminating clang responses from their response set, and that decrease in responses is significant for children who are DHH.

The models for taxonomic responses are listed below in Table 6. Figure 3 represents the number of taxonomic responses for both groups over time.

Table 5. Taxonomic responses of children with typical hearing and who are DHH

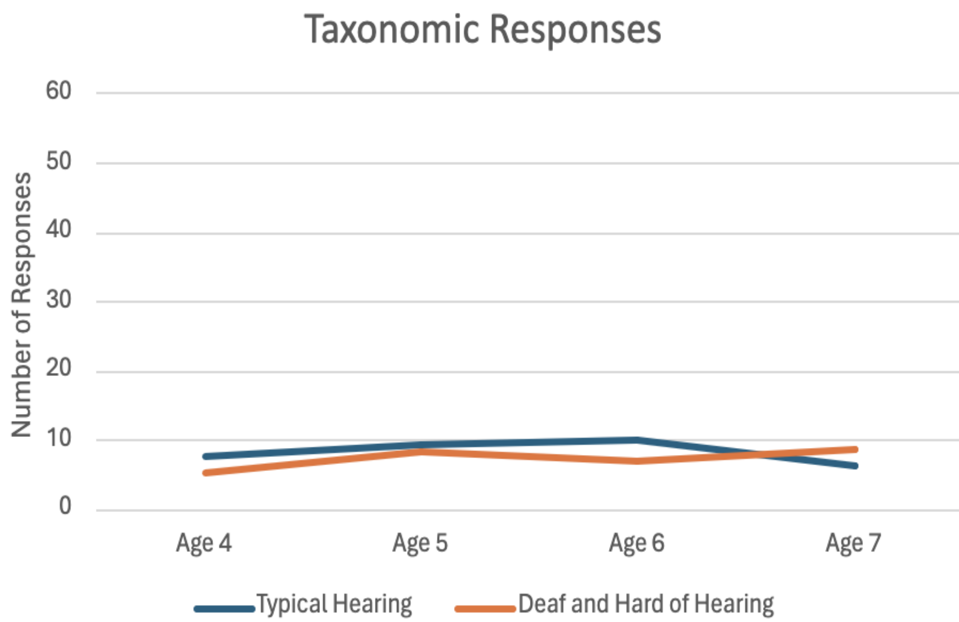
Typical hearing

	Estimate	**SE**	***t***	***p***
Intercept	8.79	1.23	7.13	<.001
Time (Centered at age 4)	-.35	.60	.57	.328

DHH

	Estimate	**SE**	***t***	***p***
Intercept	6.13	1.19	5.13	<.001
Time (Centered at age 4)	.77	.59	1.31	.196

Figure 3.



At age four (where time is centered), the expected performance for children with TH is 8.79 taxonomic responses and with each year increase, it is anticipated that children will decrease by .35 taxonomic responses on average as represented by the coefficient term associated with age. The intercept performance of children who are DHH is 6.13 taxonomic responses at age four, as time was centered at this age in this model. With each year increase in age, children increased responses by .77 responses on average as represented by the coefficient term associated with the Time variable. However, the growth rates are so minimal, indicating that neither group is exhibiting growth.

The third research question asked if children who are DHH and children with TH differ in their growth in taxonomic responses between the ages of four and seven. Growth rates were not significant for either group in this model, indicating that both groups of children are not growing in their taxonomically related responses. To evaluate differences at beginning (age four) and ending (age seven) time points, an analysis of variance compared group performances. There were not significant group differences at age four ($F(1,38) = 1.62$, $p = .211$; TH $M = 7.72$, $SD = 6.76$; DHH $M = 5.29$, $SD = 5.18$) or at age seven ($F(1,35) = 2.43$, $p = .127$, TH $M = 6.41$, $SD = 3.74$; DHH $M = 8.79$, $SD = 6.04$). Overall, it appears children are not growing in their taxonomic responses.

The models for paradigmatic responses are listed below in Table 7. Figure 4 represents the number of paradigmatic responses for both groups over time.

Table 6. Paradigmatic responses of children with typical hearing and who are DHH

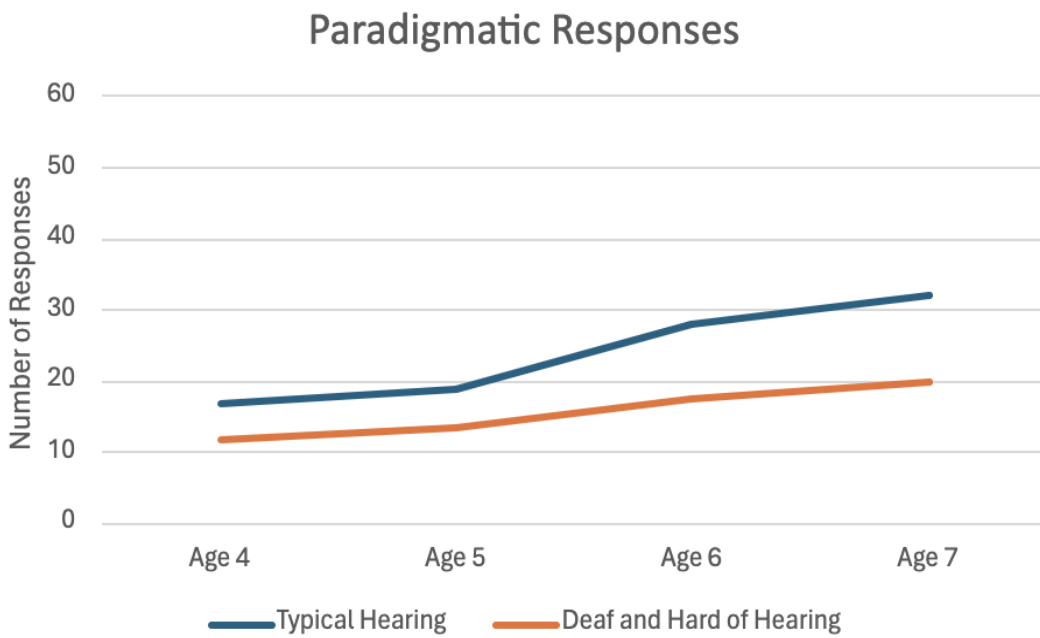
Typical hearing

	Estimate	**SE**	***t***	***p***
Intercept	17.45	1.89	9.22	<.001
Time (Centered at age 4)	.67	.74	.91	.369

DHH

	Estimate	**SE**	***t***	***p***
Intercept	12.41	1.63	7.62	<.001
Time (Centered at age 4)	2.33	.69	3.34	.001

Figure 4.



At age four (where time is centered), the expected performance for children with TH is 17.45 paradigmatic responses and with each year increase, it is anticipated that children will increase by .67 paradigmatic responses on average as represented by the coefficient term associated with age. The intercept performance of children who are DHH is 12.41 paradigmatic responses at age four, as time was centered at this age in this model. With each year increase in age, children increased responses by 2.33 responses on average as represented by the coefficient term associated with the Time variable.

The fourth research question asked if children who are DHH and children with TH differ in their growth in paradigmatic responses between the ages of four and seven. Growth rates were only significant for the DHH group in this model, indicating that children who are DHH are significantly increasing in paradigmatic responses, but children with TH are not. To evaluate differences at beginning (age four) and ending (age seven) time points, an analysis of variance compared group performances. There were not significant group differences at age four (F(1,38)

= .007, *p* = .933; TH *M* = 16.61, *SD* = 11.35; DHH *M* = 11.76, *SD* = 7.98) or at age seven ($F(1,35) = .349$, *p* = .56, TH *M* = 18.47, *SD* = 6.68; DHH *M* = 19.95, *SD* = 8.13). Overall, it appears children are increasing paradigmatic responses in their response set, and that increase in responses is significant for children who are DHH.

Discussion

The purpose of this study was to investigate the longitudinal development of the lexical-semantic organization systems of children who are DHH as compared to their typical hearing peers. Specifically, the four research questions asked if, between the ages of four and seven, children who are DHH and children with TH differ in their growth in semantically-related, clang, taxonomically-related, and paradigmatic responses.

The first research question asked about the growth of semantically-related responses in children who are DHH and children with TH. Literature demonstrates that as children get older, they will move from a sound-based lexical-semantic organization system to a meaning-based lexical-semantic organization system (Sheng & McGregor, 2010). Results showed that both children who are DHH and children with TH experience growth in their semantically-related responses. However, children who are DHH respond, on average, with numerically fewer semantically-related responses across ages. Variability in responses across DHH individuals, however, yielded a large standard deviation in performance that may have influenced the non-significant difference findings between groups. This variability is consistent with other studies of children who are DHH: there are some children who function in the same range as children with TH and many who do not. This could indicate that some children who are DHH have a less mature lexical-semantic organization system than their TH peers and might take longer to move from a sound-based organization system to a meaning-based organization system.

Results for clang responses for children who are DHH align with the previous finding that this group of children takes longer to move from a sound to meaning-based organization system. Based on our data, the average performance indicates children who are DHH do not eliminate the use of clang responses until age seven. Although we cannot confirm the statistical significance of the decrease in clang responses for children with TH, it could be inferred that this group does not use clang responses at the same rate as children who are DHH; many children in the TH group eliminated clang responses early in development and that group may have experienced floor effects on the measure.

There was no growth found for taxonomic responses for either group. It is theorized that a thematic-taxonomic shift should occur during middle childhood (Sheng et al., 2006). However, this research did not find any notable increase in taxonomic responses that would suggest the emergence of a thematic-taxonomic shift for neither children who are DHH nor children with TH. It is possible that further study of children at later ages would demonstrate a shift.

Finally, paradigmatic responses appear to be increasing for both groups, but this increase is only significant for children who are DHH. Lippman (1971) stated that a syntagmatic-paradigmatic shift should occur for children around the age seven or eight. Although we see an increase in paradigmatic responses for children who are DHH, it is unclear whether this is due to a syntagmatic-paradigmatic shift or is a result of the increase in the overall number of semantically-related responses for children who are DHH, many of which tended to be paradigmatic. Because this data tracked children through age 7, it is also possible that we are only capturing the beginning of a shift to paradigmatic responses. A descriptive interpretation of the data does seem to indicate that both groups are increasing this type of response.

Future Directions and Limitations

There are several limitations to this study that should be kept in mind when reading this research, and those limitations provide avenues for possible future directions. First, the children in this study are not as racially or ethnically diverse as the general population. The results should be interpreted as such and cannot be generalized to a child of any race. Another participant demographic limitation is that the children in this study communicate using primarily spoken language rather than sign language. These results cannot be extended to children who do communicate primarily using sign language. Future work may consider including both of those groups in these studies to determine the influence of diversity and language modality on lexical-semantic organization.

Second, because there was no increase in taxonomically-related responses across ages four through seven for both groups, future direction of study may consider including children who are older than seven. The absence of an increase in taxonomically-related responses in this study could indicate that the thematic-taxonomic shift occurs later than age seven and that age was a limitation of this study.

Next, the list of prompt words for the repeated word association task may not have been optimal for eliciting maturity transitions, especially the taxonomic and paradigmatic shifts. For example, paradigmatic shifts are easiest to see when using adjectives as stimulus words (Cronin, 2002; Nelson, 1977). It is possible that future work in this area would benefit from refining the original RWA task.

Finally, testing conditions at the Early Language and Literacy Acquisition study may lead to fatigue. At the ELLA study, participants are administered an array of language and literacy assessments. It is possible that the children's responses to the repeated word association task might not have captured an accurate representation of the maturity of their lexical-semantic organization systems when those tests were placed at the end of the testing session. The interaction between fatigue and performance on a task like the repeated word association task could be another avenue of study, particularly as children who are DHH experience chronic fatigue.

Conclusion

Both children who are DHH and children with TH are increasing in their semantically-related responses, meaning that their lexical-semantic organization systems are maturing over time. However, children who are DHH are consistently, looking at descriptive averages, producing fewer semantically-related responses than children with TH. Many children who are DHH may be delayed in their development of their lexical-semantic organizations. More information and investigation into the thematic-taxonomic and syntagmatic-paradigmatic shift is needed before conclusions can be made about these maturity changes. Additionally, characteristics of children that predict lexical-semantic maturation and contributions of that maturation to other outcomes (like literacy) are next steps that should be explored.

Deficits in lexical-semantic organization systems could lead to vocabulary or word finding deficits in school or later in life. Certain activities in academic settings that require children to categorize words or ideas and organize words or thoughts could be affected by these deficits.

Appendix

Coding Manual (adapted from Rush, Werfel & Lund (2023)):

Coding Considerations

Level of Subjectivity: While coding, keep in mind your own subjectivity when determining codes. Specific things to keep in mind:

- Age level of participants when deciding if the response is semantically related to the stimulus. Would a child of that age make that connection?
- Monitor the participant's previous responses to help select codes. For example, if the child has consistently been responding with clang/rhyming responses and the relationship you are coding is eat-meat, this would be coded as a clang (X) response due to the history of rhyming responses.

Direction of Semantic Relations:

- Most Thematic codes can be used in both the stimulus-response and response-stimulus direction. For example, yawn-tired and tired-yawn would both be coded as a causal relationship (CS).
- Syntactic relations can only be used in the stimulus-response format. For example, hide-seek would be classified as SYN, but seek-hide could not be coded as SYN.
- All taxonomic codes must be coded in the stimulus-response direction. For example, dog-poodle would be coded as a subordinate relation (SUB), but poodle-dog would be coded as a superordinate relation (SPR).

Choose the most appropriate code: Sometimes there can be more than one code that could describe the relationship between the stimulus and response. Choose the one that most appropriately describes the semantic relationship.

Repetition of response: If a child repeats the same response for the same stimulus (ex. Food for eat all three times), code the first response accordingly and code the following responses as NSR/NR.

Coding Process

Step 1: Decide if the response has any relation to the stimulus.

Semantic Relation: A response that has a semantic relationship with the stimulus word. For semantically related codes, proceed to step 2.

No Semantic Relation [NSR]: A response that does not have any relationship to the stimulus can fall in one of three subcategories:

1. Clang Response [X]: phonological relation to the word by means of alliteration or rhyme
    a. Alliteration example: cow-can
    b. Rhyme example: kite-might
    c. Nonword rhyme example: goat-loat
2. Error Response [ER]: verbal, real-word response that has no semantic or phonological relation to the prompt

a. Response that is a repetition of the stimulus: cow-cow
b. Response that inflects the stimulus: foot-feet, cry-cried
c. Response that is a real-word with no relation to the stimulus: yawn-table

3. No Response [NR]: repetition of previous response, silence for more than 20 seconds following the stimulus presentation, unintelligible responses, nonsense words (unless the nonsense word rhymes with the stimulus – code as clang)

*Code all non-semantically related responses with their specific classification code (X/ER/NR) and the NSR code.

Step 2: If response is semantically related, determine if the response has a thematic or taxonomic relationship to the stimulus.

Thematic [TH]: A response that falls into the same schema/theme as the stimulus. Thematic responses can be coded in one of five ways:

1. Function [F]: response describes the function of the object with a verb (action related to the object) or a noun (common correlates to the stimulus).
   a. Examples: read-book, eat-food, broom-clean, cow-milk
2. Descriptive [D]: response describes common characteristics of the stimulus
   a. Examples: pillow-squishy, squeeze-hard, frog-green
3. Causal [CS]: response completes a cause-and-effect relationship with the stimulus
   a. Examples: hide-scared, eat-full, push-hurt
4. Part-Whole [PW]: response represents a portion of the stimulus
   a. Examples: foot-toe, zipper-jacket, turtle-shell
   b. *For part whole relations, the part is a physical piece of the whole. This is different from the hierarchical, taxonomic relations where the sub concepts are examples of the broader category.
5. Syntactic [SYN]: response is a common word sequence that follows the stimuli in connected speech
   a. Examples: count-one, hide-seek, eat-healthy
6. Location [L]: response is a location where the object is typically found, or where the action typically takes place
   a. Examples: frog-pond, swim-pool, hat-head, yawn-bed

Taxonomic [TAX]: A response that is hierarchically related to the stimulus. Only use TAX codes when the hierarchical relationship is evident. Taxonomic codes can fall into one of three categories:

1. Superordinate [SPR]: response describes the broader category that the stimulus falls into
   a. Example: cow-animal, run-exercise, turtle-reptile
2. Coordinate [CORE]: response is a counterpart example that falls into the same broader category
   a. Example: goat-llama, food-drink, kick-punch
   b. Synonyms: run-jog, house-home
   c. Antonyms: run-walk, happy-sad

3. Subordinate [SUB]: response is an part of the broader category that the stimulus encompasses
    a. Example: animal-cat, shoe-sneaker

*Code all SR responses with their specific classification code and the TH/TAX code.

For all SR responses, continue to step 3.

Step 3: Decide the sequence that the response has. The sequence will be one of the following:

Syntagmatic sequence [SS]: a response that is a different part of speech than the stimulus. For example, if the stimulus is a verb (eat) and the response is a noun (food), this would be coded as SS.

Paradigmatic sequence [PS]: a response that is the same part of speech as the stimulus. For example, if the stimulus is a noun (foot) and the response is also a noun (toe), this would be coded as PS.

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