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Lexical-Semantic Access and Organization in Children who are Hard of Hearing: Evidence from Verbal Fluency Tasks

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A thesis submitted in partial fulfillment of the requirements
for graduation with Honors in the Speech Pathology and Audiology

Elizabeth Walker
Thesis Mentor

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ABSTRACT

Language acquisition is complex. Auditory access supports spoken language acquisition. Children with hearing loss have limited auditory access and therefore are at risk for poorer language outcomes compared to typical hearing peers. Because children who are hard of hearing (HH) develop language via degraded auditory input, they have reduced access to the fine-grained phonological information that comprises words. Their limited auditory access can also cause children who are HH to hear words in fewer semantic contexts than children with typical hearing (TH). These differences in phonological sensitivity and semantic knowledge may lead to weaker lexical-semantic representations in children who are HH. The current study uses a verbal fluency task to address the following research questions: (1) do children who are HH and children who are TH differ in their lexical-semantic organization, (2) do children who are HH and children who are TH differ in their use of phonological and semantic clustering strategies, and (3) what is the effect of age on verbal fluency performance for children who are HH and children who are TH? We predict children who are HH to generate fewer words in both phonemic and semantic verbal fluency subtests and use semantic strategies more than children who have TH, exposing an effect of age for only children who have TH. Eighteen children who are TH and 25 children who are HH completed a verbal fluency task. Results partially supported our predictions; similar performance in total words, clusters and cluster size, and clustering strategy while there was a moderate effect on age for children who are TH only. A better understanding of the underlying lexical-semantic organization system in children who are HH will inform more effective treatment approaches, which could carry over to improved literacy and academic success.

INTRODUCTION

Language acquisition is complex. Desirable spoken language outcomes arise with better auditory access. Auditory access includes clarity, loudness, and ability to hear speech sounds in an environment. In reality, most communicative interactions do not provide great auditory access. Signals degrade by distance, background noise, vocal quality of the speaker, and hearing ability of the listener. Children who are hard of hearing (HH) are at risk for language deficits due to inconsistent auditory access. Children who are HH have reduced access to the fine-grained phonological information that comprises words because they develop language via degraded auditory input. Their limited auditory access can also cause children who are HH to hear words in fewer semantic contexts than children with typical hearing (TH). These differences in phonological sensitivity and semantic knowledge may lead to weaker lexical-semantic representations in children who are HH (Wechsler-Kashi, Schwartz, & Cleary, 2014). The purpose of the current thesis is to use verbal fluency tasks to investigate the lexical and semantic organization of children who are HH.

With stronger lexical-semantic representations, individuals have more automatic access to the phonological forms of words stored in their mental lexicon. They also have a deeper, more detailed understanding of word meanings. Strong lexical-semantic representations are important when listening to running speech during conversation. Individuals can actively predict what acoustic information is coming next by attending to related words. A larger lexical-semantic network helps the listener process the acoustic signal and understand the message. Finding meaning in running speech is a demanding task, and children who are HH may be at an even greater deficit if their lexical-semantic representations do not support active prediction processes to find the meaning of a message. In the current study, a verbal fluency task is used to capture the expressive ability of children who are HH and TH in order to compare the lexical-semantic networks between the two groups.

Verbal Fluency

Language is comprised of levels of complexities, which are stored separately. For example, phonology is separate from semantics. Phonology is the storage of meaningful sounds in a lexical-semantic network. The sounds that comprise an individuals' native language are referred to as their phonemes. At a higher level, semantics refers to the storage of meaningful words within the language. The different levels of complexities are used to access words and their word meanings.

Verbal fluency is a way to measure language access and organization across two levels of language complexity: phonology and semantics. The task requires individuals to list as many words they can think of after given a specific prompt. There are two types of verbal fluency measures. Phonemic verbal fluency requires retrieval of words beginning with the same letter. Semantic verbal fluency requires retrieval of words in the same kind of category. Assumptions about lexical-semantic access and organization can be drawn from the responses and the strategies employed during the task.

An efficient response would include an understanding about the relationships between words. If connections between two words are strong, the words are more accessible than two words with little relationship. For example, "dog" is more likely to activate "cat" than it is "shark" because dogs share more semantic features with cats than they share with sharks. Individuals with well-defined phonological representations will be easily able to retrieve words starting with a particular letter or sound, so they will name more in the phonemic task. Similarly, people with stronger semantic connections will name more words in the semantic verbal fluency task because strong semantic connections facilitate lexical retrieval from long-term memory. Also, individuals have unique word relationships based on experience. Therefore, verbal fluency results vary across individuals. Analysis of a population determines trends in verbal fluency strategies and an idea about organization of lexical-semantic networks.

An important component of fluency performance is clustering. Clustering includes producing words within a semantic or phonemic subcategory (Troyer, Moscovitch, Winocour, 2000; Classon, Löfkvist, Rudner, Ronnberg, 2014). Further, the size of a cluster provides insight into the individual's organization of linguistic representation (Classon et al., 2014). For example, with a larger cluster, linguistic representations are more accessible and efficiently organized for appropriate responses. Clustering and cluster sizes are verbal fluency strategies that expose access and organization of linguistic representations.

Verbal fluency can be analyzed by strategy and by factors that influence performance. Investigating factors that may interact with performance in the verbal fluency task can help with explaining outcomes. More specifically, looking at factors like age and hearing status can help summarize results to predict lexical-semantic characteristics of similar children, different than the strategy used per individual.

Age

Age has an impact on verbal fluency performance due to vocabulary size and matured mental organization. Löfkvist, Almkvist, Lyxel and Tallberg (2012) compared 6- and 7-year-olds to 8- and 9-year-olds with TH and cochlear implants. They found that older ages were associated with greater word retrieval, especially in the phonemic task. Older age influences verbal fluency on the basis that more language experience leads to the ability to retrieve more words and use better strategies to do so. Further, the more language exposure an individual has, the more organization is able to develop, and language becomes more accessible.

Potential trends in linguistic abilities can emerge when comparing children with TH and children who are HH at different ages. Walker et al. (2019) compared children who are TH and HH at first and third grade in a time-gated word recognition task. Results of this study show third-grade children with TH utilized semantic context more than the third-grade children who are HH. In comparison, first-grade children who are TH and HH showed no difference on performance. These findings highlight a gap between same age peers based on hearing status. While children who are HH appear to be on track during the early school years, they can fall behind in performance within the next few years. Differences in hearing status and access to phonetic variation and semantic contexts can lead to the difference in lexical-semantic network development during school-age years. A limitation of the time-gated task used in Walker et al., however, is that it relies on the child's auditory access and receptive language skills in the moment. An expressive task of lexical-semantic ability, like a verbal fluency task, can provide more insight into the size and organization of the mental lexicon.

Hearing loss

Hearing loss causes inconsistent auditory access, which can weaken linguistic representations. Furthermore, the phonemic verbal fluency task would be more difficult for children who are HH. Löfkvist, Almkvist, Lyxel and Tallberg (2014) found a significant difference in phonemic verbal fluency ability between 8-9-year-olds with cochlear implants and those with TH. The individuals with cochlear implants retrieved fewer words overall and used fewer clusters and switches during the tasks. Therefore, poorer phonetic access and organization may develop with a shallower understanding of sounds in the individual's language.

Individuals with hearing loss are likely to have better semantic ability relative to their phonological abilities. Word meaning and lexical representations rely less on fine-grained speech sounds to develop than phonological representations do. Wechsler-Kashi, Schwartz, and Cleary (2014) found that children with cochlear implants named significantly fewer words in both phonemic and semantic tasks as well as producing fewer clusters in the phonemic task but performed no differently in the semantic task. The authors summarized their findings to say children with cochlear implants performed relatively better on the semantic than the phonological task (Wechsler-Kashi, Schwartz, & Cleary, 2014). Alternatively, the phonemic task may be inherently more difficult than the semantic task, regardless of hearing status. Marshall et al. (2018) conducted a study comparing children who are deaf and hard of hearing to children with TH in a semantic verbal fluency task. Deaf children produced fewer total words than TH peers. Cluster size did not differ between groups, and both groups shared 9/10 of their most frequent responses (Marshall et al., 2018). Measuring the most frequent responses between the two groups can demonstrate that children who are deaf can perform similarly to TH peers despite acquiring semantic representations through different modes of input.

Most previous studies examining verbal fluency have included children with cochlear implants, not hearing aids. Many research teams group any degree of hearing loss together into one category, despite individuals with cochlear implants being fundamentally different than individuals who are HH. It is important to distinguish children who are HH separate from children who have cochlear implants because they have access to quantitatively different auditory signals. In this study we will investigate the underrepresented population of children who are HH.

Our Study

Populations in the research literature focus on individuals with TH, as well as individuals with cochlear implants. The current study is primarily interested in children who are HH. These children use hearing aid amplification and are an under-researched population. Children who are HH may be predicted to perform the same as the cochlear implant users, due to degraded auditory access. In opposition, the individuals who are HH may have significantly better auditory access than individuals with cochlear implants have, resulting in stronger lexical-semantic connections. Therefore, more specific research concerning children who are HH is important to clarify their lexical-semantic abilities.

The current study will look at expressive ability. More specifically, prompting the individual with a question grants a verbal response to gain insight on their internal lexical-semantic knowledge. Using the verbal fluency task to elicit expressive capabilities has an advantage in emphasizing the connections between words in real time, rather than analyzing strategies employed on a standardized test. Verbal fluency allows individuals to respond in any approach they seem fit, without restriction.

This study is concerned with children with hearing loss who are at a critical age for linguistic development. Without developed lexical-semantic skills, further concerns may occur involving literacy and academic success. With better understanding of the underlying lexical-semantic organization system children who are HH have, a more effective treatment process can be used to address weaker representations or connections.

To that end, this study will address the following research questions:

1. Do children who are HH and children who are TH differ in their lexical-semantic organization? We predict that children who are HH will generate fewer words in both phonemic and semantic verbal fluency subtest due to a degraded signal.

2. Do children who are HH and children who are TH differ in their use of phonological and semantic clustering strategies? We predict that children who are HH will have fewer total clusters and a smaller average cluster size. Further, children who are HH will employ more semantic-based search strategies within phonemic and semantic tasks, compared to TH peers.
3. What is the effect of age on verbal fluency performance for children who are HH and children who are TH? We predict that comparing children ages 8-9 to ages 10-12 will show an effect of age for the children who are TH but not for the children who are HH.

<u>METHOD</u>

Most participants were enrolled in a larger study on lexical and semantic processing in children who are TH and HH. The rest were recruited through word of mouth. The study was approved by the Institutional Review Board at the University of Iowa.

Participants

Forty-three children ages 8-12 years old participated in this study. Children were native English speakers with no cognitive or language disabilities other than possible delays related to hearing loss, if applicable. Children were excluded if they primarily used a manual form of communication or scored 1.5 standard deviations below the normative mean on a nonverbal intelligence scale.

Children who are TH: Children with TH were recruited from the Iowa City area. These children were included if they also passed a hearing screening at 20 dB HL at 500, 1000, 2000, and 4000 Hz in both ears.

Children who are HH: Children with hearing aids were recruited through the Outcomes of Children with Hearing Loss (OCHL) study (Tomblin et al., 2015). They were given a full audiogram to determine hearing status.

The children fell into four groups based on hearing status (TH and HH) and age. A total of 25 children who are HH with a mean age of 10.76 years (SD of 1.14) and 18 children who are TH with a mean age of 10.61 (SD of 1.03) participated. To divide the children into age groups for analysis, the younger group was below 10 years old: 8 children who are HH and 7 children who are TH. The older group was 10.75 years old and above: 15 children who are HH and 10 children who are TH.

Procedures

The verbal fluency task began with the phonemic task, then the semantic task. The children were first given directions for the task to not include numbers, people, places, or different forms of the same word. A practice task was completed before each task to ensure understanding (i.e., letter M before the phonemic task and types of clothing before the semantic task).

The phonemic task requires the children to say as many words as they can think of that begin with the letter F, A, and S within the time limit of 60 seconds, for each letter. The semantic task followed, which asked the children to say as many words as they can think of that fit into a category within 60 seconds, specifically animals, then types of food. The responses were recorded as a voice memo on a mobile device for later transcription. Instructions required verbal confirmation by the child that they understood the task before it began and allowed for encouragement while the participants seemed at a loss of responses before time was up.

Statistical Analysis

Verbal fluency data were transcribed per child. Reliability was determined by training a lab member to transcribe 20% of the data and compare the transcription with the main transcriber. Reliability was attained at 98%.

Clusters: These data were analyzed by semantic or phonemic subcategory, called clusters. A phonemic cluster is classified if at least two successive words began with the same two letters (i.e., frog, French), alter by one vowel sound (i.e., fear, far), or rhyme (i.e., free, flee). Semantic clusters are defined by two or more successive responses belonging to the same subcategory (i.e., farm animal or pet). In the instance where a smaller category is within the larger subcategory, the larger cluster size is counted (i.e., dog, cat, kitten, fish would count as one "pet" cluster rather than parsing cat and kitten into a smaller "feline" category). For a more in depth explanation on coding the verbal fluency task, refer to the appendix.

To address age differences, children were separated into two groups: between 8-9 years and 11-12 years. Dependent variables included total number of words generated, number of clusters, and mean cluster size for the phonemic and semantic tasks. We analyzed the data by semantic or phonemic subcategory, called clusters. To quantify the extent to which children relied on phonologically and semantically based lexical retrieval strategies, we calculated the number and size of phonemic and semantic clusters for both the phonemic and semantic tasks. Independent-sample two-tailed *t*-tests were used to compare the children with TH and the children who are HH on the total number of words named, number of clusters, and mean cluster size in the phonemic and semantic tasks. Two-way ANOVAs were used to analyze the effects of age and hearing status on the total number of words named in the phonemic and semantic tasks.

RESULTS

Research Question 1: Total Words Produced

Total words: Table 1 shows results from the phonemic and semantic verbal fluency tasks by group. The difference in total words in the phonemic task approached significance with a moderate effect size, $t(41) = -1.85$, $p = 0.07$, $d = .56$ (Figure 1). Children with TH tended to produce more total words in the phonemic task compared to children who are HH. There was no significant difference in total words named in the semantic task, $t(39) = -1.54$, $p = 0.13$, $d = .49$ (Figure 2).

Dependent variables	**HH** Mean (SD)	**TH** Mean (SD)
Phonemic task total words	19.6 (5.09)	22.83 (6.38)
Semantic task total words	31.21 (8.14)	35.06 (7.55)
Phonemic task, total phonemic clusters	4.04 (1.65)	3.89 (1.49)
Phonemic task, total semantic clusters	2.72 (1.84)	2.72 (1.45)
Semantic task, total semantic clusters	8.83 (2.63)	9.82 (2.63)
Semantic task, total phonemic clusters	.88 (.95)	.12 (.86)
Phonemic task, Phonemic cluster size	1.18 (.51)	1.29 (.35)
Phonemic task, semantic cluster size	.86 (.73)	.93 (.52)
Semantic task, semantic cluster size	1.84 (.55)	1.83 (.64)
Semantic task, phonemic cluster size	.09 (.95)	.53 (.90)

Table 1: Results of phonemic and semantic verbal fluency tasks by hearing status. Values expressed as Mean (standard deviation). HH = hard of hearing, TH = typical hearing.

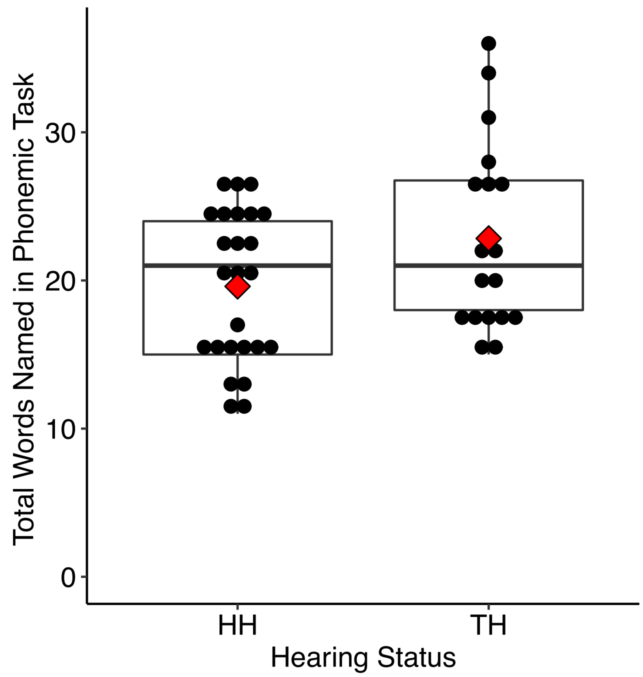

Figure 1: Total words named in the phonemic task by hearing status. Dark horizontal bars indicate median values and red diamonds indicate mean values. Boxes represent 25^{th}-75^{th} percentiles (interquartile range), and whiskers extend to the smallest and largest values. HH = hard of hearing, TH = typical hearing.

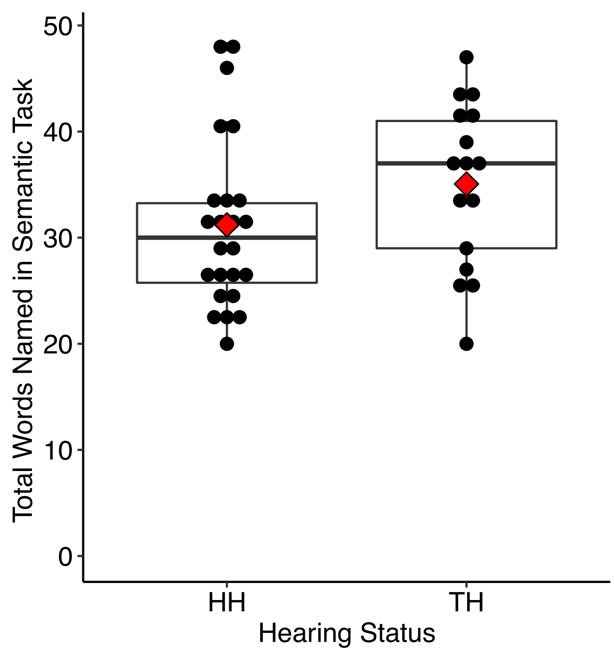

Figure 2: Total words named in the semantic task by hearing status. Dark horizontal bars indicate median values and red diamonds indicate mean values. Boxes represent 25^{th}-75^{th} percentiles (interquartile range), and whiskers extend to the smallest and largest values. Dots outside of whiskers represent outliers in the data. HH = hard of hearing, TH = typical hearing.

Research Question 2: Clustering Strategies

Number of clusters: Results of number of clusters from the phonemic and semantic verbal fluency tasks by group are shown in Table 1. Number of phonemic clusters produced did not statistically differ between children who are HH and children who are TH in the phonemic task, $t(41) = 0.31$, $p = 0.76$. Number of semantic clusters produced did not statistically differ between children who are HH and children who are TH in the phonemic task, $t(41) = 0.00$, $p = 1.00$.

Number of semantic clusters produced did not statistically differ between children who are HH and children who are TH in the semantic task, $t(39) = -1.19$, $p = 0.24$. Number of phonemic clusters produced did not statistically differ between children who are HH and children who are TH in the semantic task, $t(39) = -0.84$, $p = 0.41$.

Cluster Size: Results of cluster size from the phonemic and semantic verbal fluency tasks by group are shown in Table 1. No combination of phonemic and semantic was statistically significant. Phonemic cluster size did not statistically differ between children who are HH and children who are TH in the phonemic task, $t(41) = -0.79$, $p = 0.43$. Semantic cluster size did not statistically differ between children who are HH and children who are TH in the phonemic task, $t(41) = -0.36$, $p = 0.72$.

Semantic cluster size did not statistically differ between children who are HH and children who are TH in the semantic task, $t(41) = 0.10$, $p = 0.92$. Phonemic cluster size did not statistically differ between children who are HH and children who are TH in the semantic task, $t(41) = -1.54$, $p = 0.13$.

Research Question 3: Age and Hearing Status

Results from the interaction between age and hearing status for the phonemic and semantic tasks are shown in Figure 3 and 4. The interactions between age and hearing status were analyzed by two-way ANOVAs. There was no effect of age group ($F(1,36) = .65$, $p = .43$) or hearing status ($F(1,36) = 2.34$, $p = .14$) for children who are HH or children who are TH in the phonemic task. There was also no interaction between hearing status and age group for the phonemic task ($F(1,36) = .70$, $p = .41$). While age group was statistically significant, ($F(1,34) = 4.88$, $p = .03$), hearing status was not ($F(1,34) = 2.11$, $p = .16$) in the semantic task. There was also no interaction between hearing status and age group in the semantic task ($F(1,34) = 2.30$, $p = .14$).

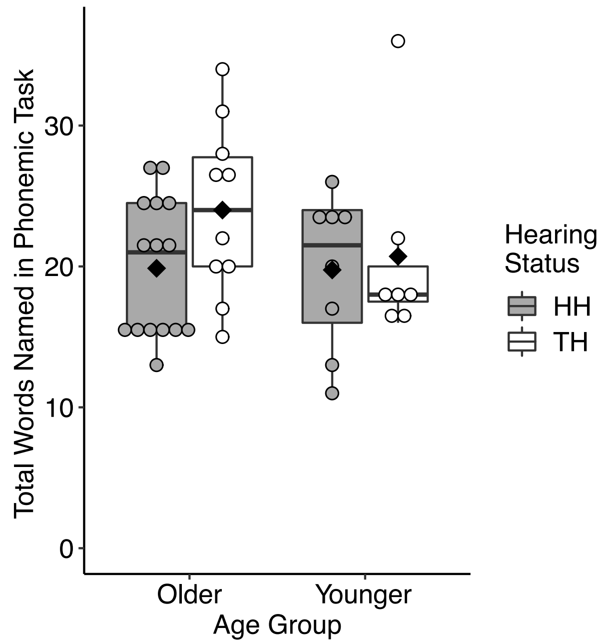

Figure 3: Total words named in the phonemic task by age group. Shaded boxes indicate children who are HH and clear boxes indicate children who are TH. Dark horizontal bars indicate median values and shaded diamonds indicate mean values. Boxes represent 25th-75th percentiles (interquartile range), and whiskers extend to the smallest and largest values. Dots outside of whiskers represent outliers in the data. HH = hard of hearing, TH = typical hearing.

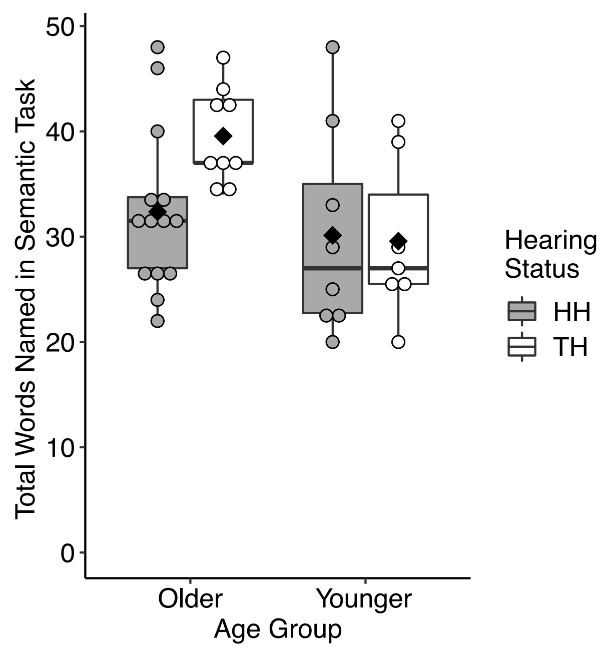

Figure 4: Total words named in the semantic task by age group. Shaded boxes indicate children who are HH and clear boxes indicate children who are TH. Dark horizontal bars indicate median values and shaded diamonds indicate mean values. Boxes represent 25th-75th percentiles (interquartile range), and whiskers extend to the smallest and largest values. Dots outside of whiskers represent outliers in the data. HH = hard of hearing, TH = typical hearing.

DISCUSSION

The primary goals of the study were to understand the lexical-semantic representations of children who are HH in comparison to children who are TH. The use of a verbal fluency task can provide insight into lexical-semantic representations based on the expressive ability of children who are at a critical age for linguistic development. We predicted children who are HH would produce fewer total words, fewer number of clusters, and have smaller cluster size while using semantically based search strategies throughout the task, compared to children who are TH. The findings of this study partially aligned with the predictions stated.

Research Question 1: Total Words Produced

In this study, we predicted children who are HH would generate fewer words in both phonemic and semantic tasks due to weaker organization of the lexical-semantic network. Results of this study partially support the prediction, demonstrating children who are TH and HH did similarly on the semantic task but differently on the phonemic task. The difference on the phonemic task approached significance and had a relatively large effect size. More specifically, children who are HH produced fewer total words in the phonemic task than children with TH while producing about the same total number in the semantic task. These data can be attributable to underdeveloped lexical organization due to degraded auditory signal. Further, the degraded signal that children who are HH rely on may be granting them less sufficient understanding of phonemic categorization and boundaries than children who are TH. The two groups performed similarly on semantic tasks because children who are HH make up for the auditory deficit through common semantic categorization trends (pets) opposed to relying on phonetic qualities (start with P).

Research Question 2: Clustering Strategies

The study predicted children who are HH would have lower totals on number of clusters used and cluster size, while relying more on semantic-based search strategy than children who are TH. The results were inconsistent with the prediction, as both groups had similar number of clusters and cluster size. They also appeared to use the strategy that corresponded to the task, rather than relying on a semantic search in both the phonemic and semantic tasks.

The lack of significant differences could be attributable to number of clusters and cluster size not being a representative measure of lexical-semantic network organization. If use of cluster and cluster strategy during verbal fluency does not tap into lexical-semantic organization, the results reported may not measure what we are claiming it to show. Second, verbal fluency is a production task that may influence results. The production aspect can demand different performance and strategy relative to a receptive task. Therefore, while some receptive tasks report differences in lexical-semantic representations between children who are TH and HH, this expressive task may not (Classon et al., 2014; Jerger, Tye-Murray, Damian, Abdi, 2013). During a receptive measure, different strategies are enforced between groups and during an expressive measure that adds an additional component to performance, the two groups perform similarly.

Research Question 3: Age and Hearing Status

This study predicted that comparing younger and older children would show an effect of age for the children who are TH but not for the children who are HH. While the interaction between age and hearing status was not statistically significant for the phonemic and semantic task, the effect size in the semantic task was moderate. The lack of significant interactions may be due to the underpowered sample size. When looking at Figure 4, the interactions are not statistically significant, but visually appear to show a trend towards a significant interaction. Therefore, more subjects may provide a more definitive picture of the interaction between hearing status and age that our sample size is not demonstrating. In the semantic task specifically, Figure 4 appears to have no effect of hearing status in the younger children but at an older age, the children with TH are naming more than the children who are HH. Overall, the plots seem to show an effect of age in the children who are TH and not in the children who are HH. These data provide trends consistent with Walker et al. (2019), where there is a gap that develops in linguistic performance and children who are HH fall behind their same age peers. Therefore, while children who are HH seem to be caught-up and performing similarly to same age peers, over time they fall behind. This trend is important because it shows the children who are TH to produce more words with age unlike the children who are HH. These data provide reason to longitudinally assess the lexical-semantic ability of children who are HH. While the children who are HH seem to be caught up to same age peers at the younger age, the children who are HH do not keep up developmentally at the older age comparison. Children who are HH may be overlooked if only relying on lexical-semantic capabilities at a younger age. Therefore, monitoring the lexical-semantic development of children who are HH over time is important to prevent a gap in performance compared to TH peers.

Clinical Implications

The results of this study support monitoring children who are HH through school years to ensure their lexical-semantic abilities are improving. This study emphasized that there could be an effect of age on children who are TH but not on children who are HH. Clinicians should continue to monitor progress of children who are HH to prevent plateaus in performance. In this way, a stronger lexical-semantic network can be developed for children who are HH. Relying on a more robust understanding of words, their associated meanings, and their relationships between other words can then supplement literary and academic performance for children who are HH.

Further, to assess a child's language ability, traditional standardized assessments may not be representative of the child's performance. Rather, an assessment that is open ended and expressive in nature may allow the child to respond without restriction. Realistically, a standardized test that is necessary to assess a child's ability should be paired with an open-ended measure to encompass a realistic picture.

Limitations and Future Directions

The small sample size used in this study could contribute to a lack of statistical significance. A larger sample size may provide a better representation of the interaction between hearing status and age in this way. Therefore, a further direction of studying lexical-semantic representations may begin with a similar study design but a larger sample size. Additionally, our study did not capture a component of verbal fluency called switches. Switches may expose lexical-semantic representations different than total clusters or total number of words. Wechsler-Kashi et. al. (2014) compared children with cochlear implants to have significantly fewer switches in the phonemic task, and no difference in the number of switches in the semantic task, when compared to children with TH. Classon et al. (2014) had similar results where individuals who are HH produced significantly fewer switches in the phonological task compared to individuals with TH. Switches may be an important factor of verbal fluency that this study did not demonstrate. A future project may then provide description about verbal fluency as a task and how all of its components (clusters, switches, total words) relate to each other. Many verbal fluency tasks are being performed but little evidence is out there explicitly stating the relationship between the subcategories and what it may be tapping into. Overall, a larger sample size and deeper understanding about switches in relationship with the other subcategories are promising future directions.

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APPENDIX

Total Correct Number

Count the total number of correct responses for each category: F,A,S, animal, food. Errors and repetitions were not included.

- Exclude repetitions (e.g., *cat*, *dog*, *cat* - only the first *cat* is counted)
- Exclude errors which are responses that do not fulfill the task requirement (e.g., naming words that are not animals or words that do not begin with the letter F)
- For phonemic fluency, exclude proper names (e.g., *Fred, Frank*) and repetitions of the same word with a different ending (e.g., *Fly, Flying)*
- For semantic fluency, exclude subcategory labels (e.g., *bird*) if specific exemplars are also given (e.g., *robin*, *canary*).
- For semantic fluency, exclude sex-specific and age-specific names of the same animal species (e.g., *hen* and *rooster*, *cat* and *kitten*). Consider them to be the same animal and only count one response.

Errors

Count the total number of errors within each category: F, A, S, animal, food.

Repetitions

Count the total number of repetitions within each category: F, A, S, animal, food.

Mean Cluster Size

Mean cluster size was counted starting with the <u>second word</u> in a cluster. That is, a single word was given a cluster size of 0, two words had a cluster size of 1, three words had a cluster size of 2, and so forth. Errors and repetitions were NOT included. (Taken from Troyer et al., 1997 and Hall et al., 2017)

Average out all of the true clusters for each task: Phonemic and semantic. ex: average of all cluster sizes from animal and food responses for one, overall, semantic mean cluster size.

Total Number of Clusters – Semantic Fluency

Clusters are defined as successively generated words belonging to the same semantic subcategories, such as

- African animals, Australian animals, North American wild animals, Pets and individual zoological categories, such as birds, canine, insects, primates, etc.

Total Number of Clusters – Phonemic Fluency

Clusters are defined as successively generated words that:

- Begin with the same first two letters (e.g., *arm* and *art*)
- Differ only by a vowel sound regardless of the actual spelling (e.g., *sat*, *seat*, *soot*, *sight*, and *sought)*
- Rhyme (e.g., *sand* and *stand*)
- Are homonyms which are words with two or more different spellings as indicated by the participants (e.g., *some* and *sum*)