PRIMING OF PART-WHOLE RELATIONSHIPS USING LEXICAL SEMANTIC NETWORKS IN CHILDREN WITH COCHLEAR IMPLANTS

by

Joshua Rucker

Bachelor of Science, 2015

Texas Christian University

Fort Worth, Texas

Submitted to the Graduate Faculty of

Harris College of Nursing and Health Sciences

Texas Christian University

in partial fulfillment of the requirements

for the degree of

Master of Science

May 2018

2016-2018

APPROVAL PAGE

PRIMING OF PART-WHOLE RELATIONSHIPS USING LEXICAL SEMANTIC NETWORKS IN CHILDREN WITH COCHLEAR IMPLANTS

A Thesis for the Degree of

Master of Science

by

Joshua Rucker

Thesis Approved by:

Dr. Emily Lund, Ph.D., Thesis Advisor

Dr. Naomi Ekas, Ph.D., Committee Member

Dr. Danielle Brimo, Ph.D., Committee Member

Dr. Debbie Rhea, Associate Dean
Harris College of Nursing & Health Sciences

ABSTRACT

PRIMING OF PART-WHOLE RELATIONSHIPS USING LEXICAL SEMANTIC NETWORKS IN CHILDREN WITH COCHLEAR IMPLANTS

By Joshua Rucker

Davies School of Communication Disorders

Texas Christian University

Thesis Advisor: Dr. Emily Lund, Ph.D.

This study aimed to explore whether children with cochlear implants have flexibility in their access to semantic networks using a novel semantic-priming task.

Children were divided into three groups: children with cochlear implants, age-matched children, and vocabulary-matched children.

Participants were asked to label pictures under three priming conditions in order to target the participants' semantic associations. Effects of semantic priming were measured by variance in labels given on target pictures.

Children with cochlear implants labeled pictures differently from typically-developing children with normal hearing. There was no correlation between group or condition and variance in labels given. Nonverbal IQ moderately positively correlated with variance in answers.

The differences in labeling may stem from a difference in quality of representations within the lexical-semantic networks. Results from the priming task argue that the construct measured by the task is likely not access to semantic networks. Instead, the task may have measured cognitive flexibility.

ACKNOWLEDGEMENTS

Thank you to Harris College of Nursing and Health Sciences and TCU Graduate Studies for their generous financial support that allowed me to travel to Los Angeles to share my project with experts outside of TCU. Additionally, data collection was made possible through the financial support of NIH NIDCD R03DC015078-01 (PI: Lund)

I would like to thank Dr. Emily Lund, my thesis advisor, for all of the support, guidance, and resources provided over the past two years. Her involvement in this project and passion for her work helped me discover my interest in speech and language research.

I would also like to thank Dr. Danielle Brimo and Dr. Naomi Ekas, the other two members of my thesis committee, for their expertise and valuable feedback given throughout the course of this project.

Lastly, thank you to all of my friends and classmates for the support and encouragement. I appreciated seeing so many of them there for all of my presentations.

TABLE OF CONTENTS

Abstract.....iii

Acknowledgments.....iv

List of Tables.....v

Chapters

Introduction.....7

Method.....13

Results.....18

Discussion.....22

References.....29

LIST OF TABLES

Table **Page**

Table 1. Group Characteristics and Mean Standard Assessment Scores......................15

Table 2. Example Primes..17

Table 3. Mean Responses by Type..19

Table 4. Response Type Effect Sizes..19

Table 5. Mean Responses by Part of Speech...21

Table 6. Part of Speech Effect Size...21

Introduction

Children with cochlear implants (CIs) have a lower vocabulary knowledge as compared to typically-developing peers with normal hearing (Lund, 2016). A difference in vocabulary knowledge may result in less organized semantic networks (Beckage, Smith, & Hills, 2011), as occurs with children with language disorders resulting from other etiologies. For example, Velez and Schwartz (2010) showed children with specific language impairment have weaker semantic networks as compared to their peers through the implementation of a priming task. The purpose of this study is to use a similar priming task to compare the semantic networks of children with cochlear implants to those of two groups of typically-developing children, one group matched for age and one group matched for vocabulary.

Lexical-Semantic Networks

Children with normal hearing learn words easily (e.g., Bloom, 2000). Semantic networks are formed as typically-developing children with normal hearing add new vocabulary words to their mental lexicon. Associations between new words and previously-learned words begin to form, based on their semantic, phonological, and syntactic features (Justice & Pence Turnbull, 2013). For example, if a child were to learn the word "hamster," he or she would form associations based on the semantic features of the word. Connections would be made between the new word and words with similar semantic features such as mouse, dog, and cat. When the target word is activated (i.e. when a word is retrieved to be expressed or received), other words within its semantic network are also stimulated in a theoretical process known as spreading activation. Stimulation of related words in the network is beneficial because it allows for quicker activation and retrieval of those words

(Justice & Pence Turnbull, 2013). Repeated stimulation of words strengthens the connections within its network, which can help prevent word retrieval difficulties (Justice, 2013).

Language Impairments and Lexical-Semantic Networks

Semantic networks play a valuable role in language development (e.g., Velez & Schwartz, 2010). "Late talkers," a group of children who are typically not talking by age two but do not show additional developmental delays, provide possible evidence of this. "Late talkers" are children who are at high risk for later struggles with subtle language development skills (Rescorla, Roberts, Dahlsgaard, 1997). Beckage et al. (2011) compared the organization of semantic networks of "late talkers" with those of "typical talkers." Their results showed that late talkers not only acquire vocabulary words later, but they also organize them less cohesively in their semantic networks. Robust organization and representations within a semantic network can improve retrieval and comprehension of words in the mental lexicon (Velez & Schwartz, 2010, Gray, 2005, Gray, 2006). Velez and Schwartz (2010) have shown that children with specific language impairment (SLI) have weaker representations in the mental lexicon and fewer associations in the semantic network compared to their typically-developing peers. As a result of these deficits, children with SLI may struggle to encode the semantic features of novel words, retain and comprehend those words with and without explicit instruction, and name and recognize them in context (Velez & Schwartz, 2010).

In the case of late talkers and children with specific language impairment, language difficulties are considered a "primary" impairment (Reilly, Bishop, Tomblin, 2014). That is, language struggles are a result of impaired language development and not attributed to any other secondary cause. Less is known about the lexical semantic networks of children with secondary impairment: it is possible that children who experience language delays as a result of another condition (e.g., hearing loss) develop in-tact networks because, aside from hearing loss, they are normal language learners. Thus, it is important to consider how children with hearing loss develop these underlying structures.

Language Impairments in Children with Cochlear Implants

Preliminary data indicates that children with cochlear implants have underdeveloped semantic networks. Kenett (2013) analyzed results from Wechsler-Kashi et al's (2013) study in which a verbal fluency task was given to children with cochlear implants and a group of IQ-matched children. The task required children to name as many animals as they could in one minute. By using computational network tools to analyze the responses, researchers were able to map the semantic networks of the participants. Their findings showed that the semantic networks of children in the cochlear implant group were less spread out than those of the control group. Lund and Dinsmoor (2016) studied semantic networks via a multi-level naming task. Participants completed a naming task that elicited labels at multiple taxonomic levels. Children with cochlear implants performed similarly to peers in use of subordinate levels; however, there was a significant delay in their use of superordinate labels (Lund & Dinsmoor, 2016).

Measurement of Lexical-Semantic Networks

The problem with measurement of lexical-semantic networks, however, is that they are a theoretical rather than a directly observable construct, and these networks have been measured in a variety of ways. Tasks are commonly designed to observe the relationships children have formed between words. Sheng and McGregor (2010) used a discrete word association task to examine semantic networks in children with SLI. Participants in that study were told to say the first word that comes to mind when presented with the target picture. Mann et al used a similar meaning association task in both American Sign Language (ASL) and English to measure semantic networks in bilingual deaf children. Other studies have employed mathematical formulas and computer software to map children's networks. Becakge et al (2010) took vocabulary given from the communication development inventory, used co-occurrence statistics to connect the words, and calculated the distance between the nodes. Kenett (2013) analyzed results from Wechsler-Kashi et al's (2013) study in which a verbal fluency task was given to children with cochlear implants and a group of IQ-matched children. The task required children to name as many animals as they could in one minute. By using computational network tools to analyze the correlation between responses across each item, researchers were able to map the semantic networks of the participants.

Semantic Priming

Very few studies of semantic networks of children with language difficulties currently exist, and the best way to study semantic network development in children is still being explored. Velez and Schwartz (2010) drew conclusions about the semantic networks of children with Specific Language Impairment (SLI) using a semantic priming task. By presenting participants with a prime word that is semantically related to the target about which they must make a judgment, researchers were able to observe an effect of facilitation in the typically-developing group and a lack of an effect in the SLI group. When the prime word is presented to typically-developing participants, its activation spreads throughout its semantic network, allowing for a quicker judgment to be made because the necessary concepts were already being stimulated by the activation of the prime word. Because this receptivity to semantic priming is a result of robust associations in the semantic network, it can be concluded that associations in the semantic networks of children with SLI are too weak to benefit from priming.

Priming Constructs and the Whole-Object Assumption

Interpretation of priming results is dependent on the type of relation being primed. Priming tasks have been used to measure many different areas of language. For example, Ledoux et al. (2007) measured the effects of a syntactic priming task on participants' comprehension of sentences. In their study, participants disambiguated syntactically ambiguous garden-path sentences after being presented with a syntactic prime (ie a sentence of the same grammatical structure) or an unrelated prime (a sentence with a different grammatical structure). The results showed syntactic primes elicited more positivity than unrelated primes (Ledoux, Traxler, & Swaab, 2007). The relation being primed in this study is between part and whole objects on the basis of the whole-object assumption. When children are presented with an object labeled with a novel word, for example, they will assume that the novel word is referring to the entire object, rather than a specific part. This is known as whole-object assumption (Markman, 1992). Obviously, for a child to learn a specific part of an object, this assumption must be overridden. Research has shown that this can be achieved by explicitly showing children that only a part of the object is being referenced (Kobayashi, 1999). Similarly, in naming tasks, children are more likely to give a whole-object rather than a part name (Hollich et al, 2000). Thus, one possible way of exploring semantic network access at varying levels would be to determine if semantically-related priming words can elicit a part label for an object rather than a whole-object label. If children with cochlear implants are able to override a tendency to name whole objects in favor a part label elicited by the semantic prime, this would indicate that they have flexible access to semantic networks, even if those networks are underdeveloped.

Purpose and Research Questions

Specific language impairment is a disorder affecting language in the absence of other developmental delays or hearing loss. In other words, language is the primary impairment. Children with hearing loss often have language difficulties. However, in their case, any language deficit is secondary to or a result of the impaired access to sound. Although deficits in the areas of semantics and vocabulary can be observed in children with CIs, whether or not these deficits are a result of an impairment of the underlying lexical-semantic networks remains unclear.

This study seeks to examine semantic networks in children with cochlear implants by comparing them to those of typically-developing children with normal hearing. Because semantic networks are contingent on vocabulary knowledge, the children with cochlear implants will be compared against both children of the same age and children with the same vocabulary levels. If the children with cochlear implants perform differently from the age-matched children but similarly to vocabulary-matched children, it could be posited that the development of semantic networks in children with CIs are delayed rather than impaired. However, if the CI group looks different from both control groups, it could be posited that children with cochlear implants differ from typically-developing children with normal hearing in their development of semantic networks.

The purpose of this study is to compare the effect of primes on whole-part object labeling in typically-developing children with normal hearing and children with cochlear implants. The following research questions were posed:

1. Do children with cochlear implants label pictures differently than typically developing children with normal hearing?

2. Do children with and without cochlear implants experience a facilitatory effect of a whole/part semantic priming task?

Method

All procedures in this study were approved by the Texas Christian University Institutional Review Board.

Participants

Participants included eighteen children across three different groups: seven children with cochlear implants (CI), five age-matched (AM) children, and six vocabulary-matched (VM) children.

Children with CIs met the following criteria: no known additional disabilities contributing to language or cognitive development (e.g., Down syndrome, Autism Spectrum Disorder), parents without hearing loss, no significant visual impairments, and use spoken English as a primary language in the home. Children in the CI group two cochlear implant devices of any brand (all were either Cochlear or Advanced Bionics). Age of implantation and pre-aided pure tone thresholds varied and these variables were considered as covariates in analysis. No child reported an etiology associated with progressive hearing loss.

Typically-developing children with normal hearing were recruited as chronological-age matches (AM) and vocabulary-size matches (VM) matches for children with CIs. VM children had an expressive vocabulary size that is within 5 raw score points of at least one child within the CI group according to the *Expressive One Word Picture Vocabulary Test.* AM and VM children had normal hearing as confirmed by a hearing screening (30 dB HL across 500, 1000, and 2000 Hz).

All participants completed a battery of standardized, norm-referenced assessments to measure language, articulation and cognitive abilities. Assessment given in prior to completion of the tasks were: the Primary Test of Nonverbal Intelligence (PTONI; Ehrler & McGhee, 2008), Early Speech Perception Test (Moog & Geers, 1990), the Arizona Articulation Proficiency Scale (AAPS; Fudala, 2000), and the Receptive and Expressive One Word Picture Vocabulary Tests (ROWPVT, EOWPVT; Brownell, 2000). Group characteristics and mean assessment standard scores (SS) are listed in Table 1.

Table 1

Participant Data

	Group		
	CI	AM	VM
Age in Months	71 (12.74)	77.6 (11.08)	62.33 (18.08)
Age of Identification of Hearing Loss	14.71 (10.36)		
Age of Implementation	27.71 (10.39)		
EOWPVT SS	94.71 (16.99)	117 (6.82)	110 (8.99)
ROWPVT SS	89.14 (17.53)	109 (7.78)	110.67 (11.08)
PTONI SS	103.71 (16.25)	96.8 (26.62)	98.5 (8.83)
EOWPVT Raw Score	66.43 (19.35)	95 (6.04)	71.17 (20.8)
TELD SS	85.43 (22.28)	112.8 (8.79)	110.67 (9.35)
AAPS-3 SS	89.86 (9.79)	97 (4.24)	98 (9.61)

Task Development

The twenty-one pictures used in this task had whole and potential part labels that are words that are likely to be acquired before age 5, according to the Age of Acquisition Database (Kuperman, Stadthagen-Gonzalez, & Brysbaert, 2012). Children were asked to label the pictures under three conditions: a neutral priming condition, a semantic priming condition, and an unprimed condition. To generate semantic prime words, objects in the same semantic category as the part-label target were selected (e.g. "circle" as a semantic prime for the target "square"). To generate neutral primes, words that were neither semantically nor phonologically similar to the either the part or whole label for the item were used. In the unprimed condition, no prime word was presented. The University of South Florida Free Association Norms were used to select valid semantic primes (Nelson, McEvoy, &

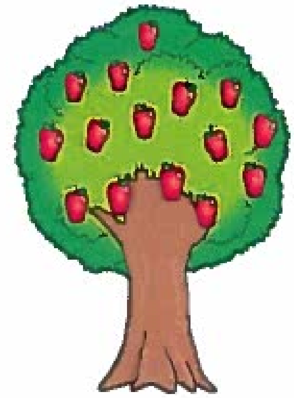
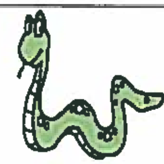
Schreiber, 1998). The prime words were produced with an audio-recording produced by a young adult male with no known speech or hearing problems using General American English dialect.

Procedures

Children were instructed to sit in front of an HP Compaq LA 2306x Monitor and name each picture as it was displayed on the screen. The task was designed and conducted using E-Prime 2.0 software® (Schneider, Eschman, & Zuccoloto, 2002). Children participated in three experimental blocks of 21 target pictures and 14 primes each. Within a block, 7 pictures were paired with a semantic prime, 7 were paired with a neutral prime, and 7 pictures were not primed. Table 2 depicts an example of a target picture and each of its corresponding primes. The order of the pictures was randomized. For priming trials, participants saw the prime 1,000 ms before the target picture was presented (Velez & Schwartz, 2010). The timing of this prime was consistent with timing of primes that show effects of semantic priming in typically-developing children with normal hearing. The next picture was presented at least 2500 ms (outside of the semantic priming window) after the participant's response.

To introduce the task to the children, the examiner presented these instructions: "We're going to play a computer game now. It's all about how fast you can say some of my picture names. A lot of times in this game you will see two pictures – you'll hear my computer name the first picture and then you will see a "plus" sign. Then, you will name my second picture as fast as you can. You can say any word that you think of in the picture, the first thing you see, okay? So, with this picture [picture in lab], I could say [give example]. Are you ready?"

Table 2
Example Primes

Condition	Prime	Target Picture
Semantic	 Banana	
Neutral	 Snake	
Unprimed	None	

The task yielded two dependent variables, response type and a variability statistic for each participant. Response types were grouped into four categories: *whole, part, both,* or *N/A* for unintelligible or irrelevant responses. Using the example in table 2, the *whole* label would be "tree," part would be "apple," and both would be "apple tree." The variability statistic was defined as any change in response type across conditions within a target label. Each participant was given a code based on whether or not the participant changed answers in the presence of a prime.

Reliability

To determine reliability for participant responses, a graduate assistant watched at least one-third of randomly-selected participant videos from each group and transcribed the children's responses to each target. To determine reliability for coding of responses into the correct categories, the graduate assistant grouped every answer for one-third of the target labels into one of the four categories. The point-by-point response agreement was 89.34%, and point-by-point agreement for grouping was 97.10%.

Statistical Analysis

Due to a small group size and use of a nominal variable, a Kruskall-Wallis one-way analysis of variance was performed to address the first research question. Effect size differences for mean number of response types between groups (continuous variables) were calculated as Cohen's d, where .7 is a large effect, .5 is medium and .1 is small. To address the second research question, relations between variables were explored with a Tau correlation analysis.

Results

The first question sought to determine if children with cochlear implants label pictures differently in a repeated labeling task from typically developing children with normal hearing. To answer this question, answers were sorted by response type (a *whole*-picture name, a *part* name, or a *whole* and *part* name). Mean number of responses for each category per the 63-trial task were calculated for each group. Mean task performance for each group is shown in table 3. From these means and standard deviations, effect sizes (Cohen's d) were used to compare differences across groups. Effect sizes are shown in tables 3 and 4.

Table 3

Mean Responses by Type (Total = 63)

	Group		
Response Type	CI	AM	VM
Whole	42.57 (7.87)	42.4 (10.64)	38.83 (4.02)
Part	12.29 (3.99)	9.2 (3.83)	8.5 (3.02)
Both	2.72 (3.68)	10 (9.27)	7.83 (5.38)
NA	5.43 (6.29)	1.4 (2.07)	7.83 (4.17)

Table 4

Response Type Effect Sizes (Cohen's d)

	Group Comparison		
Response Type	CI vs AM	CI vs VM	AM vs VM
Whole	0.02	0.6	0.44
Part	0.79	1.07	0.2
Both	-1.03	-1.11	0.29
N/A	1.61	-0.45	-1.95

A Kruskal-Wallis one-way analysis of variance was performed to assess group differences in response type. Because response type was a nominal variable and group size is relatively small, nonparametric analysis was most appropriate for this research question. There was a statistically significant difference in response type across groups ($H(2) = 4.104$, $p = .041$) with a mean rank of 555.76 for the CI group, 555.33 for AM, and 591.34 for the VM group.

The primary differences in response type occurred primarily on the *part* and *both* categories. Children with CIs were more likely to give part answers as compared to AM (d= 0.79) and VM (d= 1.07). Children with CIs were also less likely to give both answers as compared to AM (d= -1.03) and VM (d= -1.11). There were a few notable effect size differences for the whole-word and non-applicable answer types. Children with CIs gave more whole answers than the VM (d= 0.6) group. Older children in the AM group were far less likely to give *N/A* answers as compared to CI (d= -1.61) and VM (d= -1.95) children.

N/A answers included responses such as "You know," "I don't know what that is," "Red" (used as a label to several items consecutively), unintelligible utterances, or no answer given.

The second research question addressed potential facilitatory effects of semantic priming (i.e., do children with cochlear implants respond differently to primes than their peers with normal hearing). To answer this question, a variable was calculated to capture how often children changed their labels in the presence of a prime: across all three presentations of a target word, participants received a dummy code score of "1" to indicate a change in answer in the presence of a prime and a "0" to indicate no change in answer. To address the effect of priming condition (semantic prime, neutral prime or no prime) and group on the tendency to change labels across all items and participants, an analysis of variance was calculated. There was not a significant main effect of group ($F(2, 1125) = 2.31$, $p = .09$) or of condition ($F\ (2, 1125) = .06$, $p = .95$) on the tendency to provide a different picture label. A second analysis of variance assessed the effect of primes and group on the part of speech produced by a child to label a picture (with dummy codes representing the part of speech produced, such as noun, verb or adjective). There was a significant main effect of group ($F(2, 1125) = 10.70$, $p = .0$) but not of condition ($F\ (2, 1125) = .68$, $p = .51$) on the tendency to provide a different picture label. A third analysis of variance assessed the effect of primes and group on the response type produced by a child to label a picture. Again, there was a significant main effect of group ($F(2, 1125) = 3.20$, $p = .04$; consistent with the nonparametric calculation) but not of condition ($F\ (2, 1125) = 1.58$, $p = .21$) on the tendency to provide a different picture label. Thus, group placement (CI, VM or AM) affected part of speech produced and type of response (e.g., *part* or *whole* picture label) but prime type did not contribute to those differences. Order of prime presentation did not correlate with any outcome variables ($p > .05$). Perhaps unsurprisingly, part of speech response was significantly correlated with response type ($r_t = .64$, $p = .00$). Mean number of responses for each part of speech per the 63-trial task were calculated for each group. Mean task performance for each group is shown in table 5. From these means and standard deviations, effect sizes (Cohen's d) were used to compare differences across groups. Effect sizes are shown in tables 5 and 6.

Table 5
Mean Responses by Part of Speech (Total = 63)

	Group		
Part of Speech	CI	AM	VM
Noun	52.15 (5.67)	46.6 (13.69)	44.33 (5.01)
Verb	2.29 (2.63)	1.2 (0.84)	2.5 (2.07)
Adjective	1.57 (1.51)	1.8 (2.49)	1.17 (1.17)
Multiple Word	3.57 (3.87)	13 (12.73)	8.83 (5.91)
N/A	3.43 (5.44)	0.4 (0.55)	6.17 (3.87)

Table 6
Part of Speech Effect Sizes (Cohen's d)

	Group Comparison		
Part of Speech	CI vs AM	CI vs VM	AM vs VM
Noun	0.53	1.46	0.22
Verb	0.56	-0.09	-0.82
Adjective	-0.11	0.3	0.32
Multiple Word	-1	-1.05	0.42
N/A	0.78	-0.58	-2.09

To explore variables that did contribute to differences in group responses, an additional variable representing within-subject tendency to change response was calculated. Number of changes in response across the three items per participant across trials was averaged to create the new variable. Tau correlations between nonverbal intelligence score as measured by the PTONI and tendency to change responses and between the EOWPVT and tendency to change responses were calculated. A child's tendency to change responses across three opportunities to label an item was significantly correlated with PTONI standard score ($r = .63$, $p = .01$) but not with EOWPVT standard score ($r = .31$, $p = .21$).

Discussion

This study had two primary objectives: to explore differences in naming in children with cochlear implants and examine the effects of a semantic priming task on the part-whole assumption. The first question addressed differences in naming across the three groups. Children with cochlear implants were more likely to give a part answer (e.g., naming only a part of the picture as compared to the whole picture, such as saying *apple* rather than *tree*), whereas children in both control groups were more likely to give a both answer (e.g., *apple tree*) . The second question addressed potential effects of the semantic priming task. There was no correlation between variance in answers and group placement. However, nonverbal IQ and variance were moderately positively correlated.

Cochlear Implants, Lexical-Semantic Networks, and Vocabulary

Perhaps a difference in naming is expected: children with CI have documented vocabulary deficits as compared to their typically-developing, age-matched peers (e.g., Lund, 2016). However, because children in the CI group also differ from the vocabulary-matched group, one could surmise that this difference is not a simple result of delayed language and/or vocabulary. When comparing *part* versus *both* answers, the most notable difference is that *both* answers require at least two words whereas *part* answers are almost exclusively one word. In other words, differences in answer type between CI and control groups may actually be a difference in the likelihood of giving multiple-word answers. This idea is further evidenced by comparing the frequency of multiple-word answers in the part of speech table. Part of speech had a moderately positive, statistically significant, correlation with response type. Children with CIs gave significantly fewer multiple-word answers than both AM (d= -1.00) and VM (d = -1.05). These effect sizes are almost identical to the differences in *both* answers between CI and AM (d= -1.03) and CI and VM (d= -1.11). The comparisons between the CI group and the vocabulary-matched group are of particular interest because semantic networks are contingent on vocabulary. Although children in these two groups had similar vocabulary skills, their use of known vocabulary differed significantly. A difference in expressive usage of vocabulary may be a result of a difference in the quality of the representations in the children's semantic networks. Quality of expressive language may be further be explored through a task eliciting lengthier, more detailed, responses such as a picture description task (e.g., the cookie theft picture used in populations with aphasia). If this difference holds, children with CIs would be expected to give less detailed answers than children with similar levels of vocabulary knowledge.

A secondary significant difference was found in the frequency of *N/A* answers. Answers in this category were primarily categorized as such because they were unintelligible utterances or items for which the child did not give an answer. When comparing results in this category across groups, the trend shows a possible effect of delayed language and/or vocabulary on the frequency of *N/A* answers. Older children in the AM group were able to provide an appropriate answer for 97.78% of items, and the younger children in the VM group were able to provide appropriate answers for 87.57% of items. Children with CIs more closely resembled the VM children, answering 91.38% of items appropriately. Effect sizes comparing N/A answers across groups showed a large difference between CI and AM (1.61) and VM and AM (1.95) and only a slight difference between CI and VM (-0.45).

Prior research has shown children with CIs are delayed in other areas such as spoken language comprehension and expression and articulation (Niparko et al, 2010; Tobey et al, 2003). Niparko et al (2010) showed children with CIs were able to acquire spoken language at a rate significantly higher than what would be predicted by their pre-implementation baseline scores. However, children with CIs were not able to reach similar levels as their typically-developing peers with normal hearing. Given this potential to make significant linguistic gains, it is a possibility that the difference in *N/A* answers may resolve if children with CIs experience significant increases in vocabulary knowledge.

Research has shown children with CIs are quantitatively lower in vocabulary knowledge (Lund, 2016). The present study demonstrated that, when vocabulary is controlled, children with CIs use their vocabulary knowledge qualitatively differently from typically-developing children with normal hearing. A tendency to give one-word *part* over multiple-word *both* answers could be interpreted as a result of weaker access to lexical-semantic networks, preventing the activation of two unrelated words in a rapid-response task. This interpretation of the results would lead to the conclusion that children with CIs have weaker semantic networks, comparable to Velez's and Schwartz's (2010) findings in children with SLI.

Priming Constructs and Lexical-Semantic Network Measurement

Potential facilitatory effects of the priming task were measured by calculating correlations between variables and variance in answers. The only significant correlation with the Stroop-like test ($r = .36$, $p < .03$). While these correlations are small, this study provides evidence that linguistic tasks comparable to the one used in this study can be used to examine cognitive flexibility. These correlations also show a link between cognitive flexibility and language. Being able to generalize novel words to multiple contexts could fall under the previously-given definition of cognitive flexibility. Children who are more flexible may be more likely to successfully recognize novel contexts in which to use vocabulary words, resulting in more appropriate stimulation of these vocabulary words and their connections within the lexical-semantic network.

Previous studies have shown that typically-developing children can be receptive to semantic priming tasks (Velez & Schwartz, 2010). However, the priming task utilized in the Velez and Schwartz (2010) study was different from the one employed in this study. Their task was a judgement task with definitive correct and incorrect answers. This allowed for clearer measurement and interpretation of results along with a reliable gauge of reaction time. Faster reaction times in semantic priming tasks have been attributed to stronger representations in the lexical-semantic network (Neely, 1977). Children with access to robust networks experience a facilitative effect from semantic primes taking advantage of the process of spreading activation. When children are unaffected by these semantic primes, it can be concluded that connections in their semantic networks are not strong enough to benefit from spreading activation. These prior studies show that children with language impairments have weaker connections within their semantic networks.

The task in the present study was designed to determine if the lexical-semantic networks of children with cochlear implants were weaker and underdeveloped, similar to those of children with SLI. Prior studies and the present study both sought to examine the construct of lexical-semantic networks; however, rather than measuring reaction times in response to priming conditions, the present task measured picture labels in response to priming conditions. It was originally hypothesized that children would be more likely to change their labels for a picture in response to a semantic prime. The precedent set by previous semantic priming tasks led to the conclusion that if this task were a valid measure of access to semantic networks, then the typically-developing control groups would have significantly stronger correlations with variance in answers. However, the results showed the only predictor of a child's likelihood of changing their label for a picture was nonverbal IQ. Given this outcome, it is possible this task was actually priming a construct related to intelligence rather than language.

Despite the absence of a correlation between priming and variance in answers, the task piloted in this study yielded results open to speculation and further investigation. The open-ended nature of the task used in this study allowed for group differences in picture labeling to surface. It is certainly possible for these differences between children with cochlear implants and typically-developing children to stem from differing levels of access to lexical-semantic networks. Further investigation into these findings using more restrictive parameters could provide insight about the significance of these differences.

Limitations

This study could have benefited from having more participants. Hearing loss affects people from all populations, yet the participants in this study consisted of only a small, controlled, sample. Studying a larger number of participants with a more diverse range of profiles (e.g., socioeconomic status, language environment, cultural backgrounds) could have increased the power of the results and allowed us to explore the results of this task on children with varying profiles.

This was a pilot study of this semantic priming task; it did not have a prior established background in the research literature. Therefore, it was unknown if this priming task would have a similar efficacy as other, established, semantic priming tasks. Similar priming tasks have not been done with children with cochlear implants, so there are no similar studies with which to compare to examine the construct validity of the experimental task.

Future Directions

Future directions may be focused on exploring one of the two objectives of the study in isolation. To examine access to semantic networks in children with cochlear implants, replicating a semantic priming task with previously established effects would provide clearer results. After noting the effects of the established priming task, the task used in this study could be administered, and results of the two tasks could be compared to determine if this study's priming task is a valid measure of LSN access. Differences in naming could be further explored by trying this task with older children, using a more open-ended language task such as a narrative, or adding a language-impaired group.

Conclusion

Language use and development in children with cochlear implants is an area that is in need of further investigation. This study provided novel preliminary information on linguistic differences between children with CIs and typically-developing children. The findings of this study provide avenues on which additional research can build.

References

Beckage, N., Smith, L., & Hills, T. (2011). Small Worlds and Semantic Network Growth in Typical and Late Talkers. *PLoS ONE*, 6(5), e19348. https://doi.org/10.1371/journal.pone.0019348

Bloom, P. (2000) *How Children Learn the Meaning of Words*. Cambridge, MA: MIT, Print.

Brownell, R., (2000) Expressive One-Word Picture Vocabulary Test (3rd ED.). Novato, CA: Academic Therapy Publications

Brownell, R., (2000) Receptive One-Word Picture Vocabulary Test (3rd ED.). Novato, CA: Academic Therapy Publications

Deák, G. O. (2003) The Development of Cognitive Flexibility and Language Abilities. *Advances in Child Development and Behavior, Volume 31.* Elsevier, 272-274.

Deák, G. O., & Narasimham, G. (2003). Is perseveration caused by inhibition failure? Evidence from preschool children's inferences about word meanings. *Journal of Experimental Child Psychology*, 86(3), 194–222. https://doi.org/10.1016/j.jecp.2003.08.001

Deák, G. O., & Wiseheart, M. (2015). Cognitive flexibility in young children: General or task-specific capacity? *Journal of Experimental Child Psychology*, 138, 31–53. https://doi.org/10.1016/j.jecp.2015.04.003

Ehrler, D. J., & McGhee, R. L. (2008). Primary Test of Nonverbal Intelligence. Austin, TX: PRO-ED.

Fudala, J. B. (2000). Arizona–3: Arizona Articulation Proficiency Scale, Third Revision. Los Angeles, CA: Western Psychological Services.

Gray, S. (2006) The Relationship Between Phonological Memory, Receptive Vocabulary, and Fast Mapping in Young Children With Specific Language Impairment. *Journal of Speech Language and Hearing Research* 49.5: 955-69. doi: 10.1044/1092-4388(2006/069)

Gray, S. (2005) Word Learning by Preschoolers With Specific Language Impairment. *Journal of Speech Language and Hearing Research* 48.6 1452-467. doi: 10.1044/1092-4388(2005/101)

Hollich, G. J., Hirsh-Pasek, K., Golinkoff, R. M., Brand, R. J., Brown, E., Chung, H. L., Hennon, E., Rocroi, C., & Bloom, L. (2000). Breaking the language barrier: An emergentist coalition model for the origins of word learning. *Monographs of the Society for Research in Child Development*, i-135.

Kenett, YN., Wechsler-Kashi, D., Kenett, DY., Schwartz, RG., Ben-Jacob, E., & Faust, M. (2013) Semantic Organization in Children with Cochlear Implants: Computational Analysis of Verbal Fluency. *Frontiers in Psychology* 4:543 doi: 10.3389/fpsyg.2013.00543

Kobayashi, H. (1999). The influence of adults' actions on children's inferences about word meanings. *Jpn. Psychol. Res.*, 41: 35–49.

Kuperman, V., Stadthagen-Gonzalez, H., & Brysbaert, M. (2012) Age-of-acquisition ratings for 30,000 English words. *Behavior Research Methods*, 44(4), 978–990. doi:10.3758/s13428-012-0210-4

Ledoux, K., Traxler, M. J., & Swaab, T. Y. (2007). Syntactic Priming in Comprehension. *Psychological Science*, 18(2), 135–143. https://doi.org/10.1111/j.1467-9280.2007.01863.x

Lund, E. (2015). Vocabulary Knowledge of Children With Cochlear Implants: A Meta-Analysis. *Journal of Deaf Studies and Deaf Education*, 21(2), 107–121. https://doi.org/10.1093/deafed/env060

Lund, E. & Dinsmoor, J. (2016). Taxonomic Knowledge of Children with and without Cochlear Implants. *Language, Speech, and Hearing Services in Schools*, v47 n3 p236-245 Jul 2016

Markman, EM. (1992) Constraints on word learning: speculations about their nature, origins and domain specificity. In M. R. Grunnar & M. P. Maratsos (Eds.), *Modularity and constraints in language and cognition: the Minnesota Symposium on Child Psychology* (pp. 59–101). Hillsdale, NJ: Erlbaum.

Moog J., Geers A. Early Speech Perception Test. St. Louis: Central Institute for the Deaf; 1990.

Neely, J. H. (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General*, 106(3), 226–254. https://doi.org/10.1037/0096-3445.106.3.226

Nelson, D. L., McEvoy, C. L., & Schreiber, T. A. (1998). The University of South Florida word association, rhyme, and word fragment norms. http://www.usf.edu/FreeAssociation/

Niparko, J. K., Tobey, E.A., Thal, D. J., Eisenberg, L. S., Wang, N., Quittner, A. L., Fink, N. E. (2010). Spoken Language Development in Children Following Cochlear Implantation. *JAMA*, 303(15), 1498. https://doi.org/10.1001/jama.2010.451

Pence Turnbull, KL. & Justice, LM. (2013) Chapter 3 Building Blocks of Language. *Language Development from Theory to Practice*. Harlow: Pearson Education Limited, 103-04. Print.

Reilly, S., Bishop, D. V. M., & Tomblin, B. (2014). Terminological debate over language impairment in children: forward movement and sticking points. *International Journal of Language & Communication Disorders*, 49(4), 452–462. https://doi.org/10.1111/1460-6984.12111

Rescorla, L., Roberts, J., & Dahlsgaard, K. (1997). Late Talkers at 2. *Journal of Speech Language and Hearing Research*, 40(3), 556. https://doi.org/10.1044/jslhr.4003.556

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). E-Prime (Version 2.0). [Computer software and manual]. Pittsburgh, PA: Psychology Software Tools Inc.

Sheng, L., & McGregor, K. K. (2010). Lexical–Semantic Organization in Children With Specific Language Impairment. *Journal of Speech Language and Hearing Research*, 53(1), 146. https://doi.org/10.1044/1092-4388(2009/08-0160)

Tobey, E. A., Geers, A. E., Brenner, C., Altuna, D., & Gabbert, G. (2003). Factors Associated with Development of Speech Production Skills in Children Implanted by Age Five. *Ear and Hearing*, 24(Supplement), 36S–45S. https://doi.org/10.1097/01.aud.0000051688.48224.a6

Wechsler-Kashi, D., Schwartz, RG., & Cleary, M. (2013) Verbal fluency naming in children with CIs: What can we learn from children with CIs on sensitive periods for language? Proceedings of ISAAR 2013: Auditory Plasticity Listening with the Brain. 4. The symposium on Auditory and Audiological Research. August 2013, Nyborg, Denmark.

Velez, M., & Schwartz, RG. (2010) Spoken Word Recognition in School-Age Children with SLI: Semantic, Phonological, and Repetition Priming. *Journal of Speech Language and Hearing Research* 53.6: 16-28. doi: 10.1044/1092-4388(2010/09-0042)