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Comparing the semantic networks of deaf and hearing children using the DRM paradigm

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COMPARING THE SEMANTIC NETWORKS OF DEAF AND HEARING CHILDREN USING THE DRM PARADIGM

by

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Abstract

This study uses the Deese-Roediger-McDermott paradigm to investigate how deaf children with cochlear implants organize their semantic networks as compared to their hearing age-mates.

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Abbreviations

1. Cochlear Implant (CI)
2. Deese-Roediger-McDermott (DRM)
3. Normally Hearing (NH)

INTRODUCTION

Children with hearing loss often demonstrate below-average vocabulary skills, in terms of both the quantity of words they understand and use (Hayes, Geers, Treiman, & Moog, 2009; Johnson & Goswami, 2010) and the rates at which they learn new words (Houston, Carter, Pisoni, Kirk, & Ying, 2005). These deficits can greatly affect a deaf child's academic and later vocational success, as vocabulary knowledge is a key predictor of whether a child will become a successful reader and an important factor in that child's ability to use language in varied contexts and for multiple purposes (Richgels, 2004). Anecdotal evidence also suggests that children who are deaf demonstrate poor categorical knowledge (Marschark, Convertino, McEvoy, & Masteller, 2004). For example, a deaf child may know the vocabulary words *apple*, *orange*, and *banana*, but be unable to report that together these items have the categorical label *fruit*. This related deficit suggests that a potential contributing factor to deaf children's poor vocabulary skills is that they structure their mental lexica in a less efficient and more disorganized manner than their hearing peers.

Hearing children (and adults) are thought to organize their mental lexica in an "interrelated network of associated concepts" (Roediger, Balota, & Watson, 2001). The model of this concept used commonly within cognitive psychology literature involving semantic priming tasks, episodic memory tasks, and connectionist modeling is known as a semantic network. Vocabulary knowledge is organized within this network, with words represented as nodes and connections established between those nodes that are semantically associated. For example, a semantic network of concepts related to the word *doctor* could be modeled with the node representing the word *doctor* situated in the center of the surrounding associated nodes representing the words *nurse, shot, checkup,* and *medicine*. According to this model, when typically developing children and adults learn a new word, it is situated within their existing semantic networks. With continued usage, added semantic relations, and more nuanced understanding, current connections are strengthened and novel connections added. Though semantic networks can vary somewhat in terms of content and connection patterns, it is thought that the organization of words that are commonly and consistently semantically associated should be similarly connected and organized from one person to the next (Roediger & McDermott, 1995; Roediger et al., 2001).

A key concept in the semantic network model is known as spreading activation theory, whereby the activation of a node spreads to connected nodes in the network. As per the previous example, when the node representing the word *doctor* is activated, that activation spreads through the semantic network from *doctor* to the surrounding nodes, with the amount of activation decreasing with each successive layer of connections from the original activated node (Roediger et al., 2001). This spread of activation has been shown to consistently spread two and three layers out in the network in both semantic priming and episodic memory tasks (Roediger et al., 2001).

One paradigm has been used repeatedly throughout the literature to study the semantic network organization of both hearing children and adults: the Deese-Roediger-McDermott (DRM) paradigm (Metzger, Warren, Shelton, Price, Reed, & Williams, 2008; Roediger & McDermott, 1995). In this paradigm, participants are presented with lists of words, with each list consisting of words semantically related to an un-presented target word, referred to as the critical lure. As per the earlier example, a list of words that are semantically related to the critical lure *doctor* are presented, including *nurse*, *checkup*, *shot*, and *medicine*. When later given a recall or recognition task, participants often report that *doctor* was one of the originally presented words, even though it was not presented. Activation during the study of words affects performance on recall and recognition tasks, and spreading activation theory suggests that this false memory arises from the spreading activation of all the surrounding activated nodes converging on the node representing the word *doctor*. This high degree of convergence produces a level of activation for the un-presented critical lure *doctor* comparable to the level of activation for each of the presented words, potentially producing a false memory (Roediger et al., 2001). While this effect has been documented consistently in adults (e.g., Roediger & McDermott, 1995; Sugrue & Hayne, 2006), and has been seen in children as young as three (Carneiro, Fernandez, Albuquerque, & Esteves, 2007), children have been shown to demonstrate adult-like rates of false-memory intrusions by the time they are between the ages of 10 and 13 (Dewhurst & Robinson, 2004; Howe, 2006; Howe, Wimmer, Gagnon, & Plumpton, 2009; Metzger et al., 2008), especially when age-appropriate (Carneiro et al., 2007) and shorter (Sugrue & Hayne, 2006) word lists are used.

Although the DRM paradigm has been used to provide a more objective means to examine semantic network organization in typically developing children, it has yet to be used in research concerning deaf children. The present study used the DRM paradigm to gain insight into how deaf children organize vocabulary in their semantic networks. Deaf children may demonstrate lower vocabulary levels, slower vocabulary learning rates, and incomplete categorical knowledge as compared to their hearing peers because their deafness has resulted in delays in all of these areas. According to the semantic network model, deaf children’s networks may simply be impoverished, constructed in a similar fashion to those of their hearing peers, but consisting of fewer nodes and fewer connections between nodes. Another explanation for these vocabulary deficits, however, is that deaf children organize their semantic networks in a fundamentally different way from their hearing peers. These students do not simply lack certain nodes or connections in their networks but instead possess a set of nodes situated and connected in a disorganized and inefficient manner. This would suggest that deaf children's vocabulary levels and novel word learning rates are not simply delayed as compared to their hearing peers, but in fact deviant; they are approaching the task of learning vocabulary in a fundamentally different way.

In the present study, I administered the DRM paradigm to deaf cochlear implant users and their hearing age-mates, ages 10 to 13 years, to investigate whether the two groups showed comparable false memory rates of critical lures during both recall and recognition tasks. In order to control for the possibility that differences in false memory rates could simply be due to potential vocabulary delays of the deaf children (and thus simply due to impoverished semantic networks) I used DRM word lists designed to be age-appropriate for second- and third-grade students (Khanna & Cortese, 2009; Metzger et al., 2008). All of the participants in the study were reading at least at a fourth-grade level. Using reading grade level as a proxy for vocabulary knowledge allowed me to assume that all of the words contained on the DRM word lists should already be well-established within the students' semantic networks, as they should have been acquired in previous grades. As such, any differences in false memory rates between the two groups would suggest fundamental differences in semantic network organization, rather than simply impoverished networks on the part of the deaf children. I expected that the deaf students would show lower rates of false memories during both the recall and recognition tasks as compared to their hearing peers as a result of important differences in their semantic network organization.

METHODS

Participants

Five deaf children with cochlear implants (2 males, 3 females) ages 10-13 (M = 12.4 years) participated in this study. All of the children were identified with hearing loss by the age of 2 years, 6 months (range: birth – 2.5 years) and received cochlear implants by the age of 3 years, 6 months (range: 2.0 – 3.5 years). For those participants who were implanted bilaterally, the age at implantation refers to their age at the time of the implantation of the first ear. The children all used spoken language as their primary method of communication, and English was the primary language spoken in the home. At the time of their participation, all the children were in mainstream (oral-only) public schools, except one student who was attending a private auditory-oral school for deaf children. According to parent report, all participants were reading at least at the fourth-grade level, with a mean reading grade level of 6.4. Table 1 shows the individual characteristics of the participants.

The control group consisted of six hearing children (3 males, 3 females) ages 10-13 (M= 12.3). The participants all spoke English as their primary language. According to parent report, all participants were reading at least at the sixth-grade level, with a mean reading grade level of 7.7. The children were recruited from public schools in the St. Louis area.

Materials

Parent Questionnaire. The parents of all the participants were asked to complete a questionnaire about their child. The questionnaire asked for information regarding the child's age, approximate reading grade level, primary communication method, and the primary language spoken in the home. Parents of deaf children were asked to provide information about their child's hearing loss and cochlear implantation.

Recall Task. Seven lists (including one practice list) of semantically related words were chosen from two previous studies (Khanna & Cortese, 2009; Metzger et al., 2008) that created lists of words for the DRM paradigm that are age-appropriate for children reading at the second- or third-grade level. In the literature, word lists of various lengths (ranging from 7-16) have been administered to children during the DRM paradigm. I chose to use word lists consisting of eight words, because shorter word lists have been shown to increase the number of false memory intrusions of both children and adults (Sugrue & Hayne, 2006). Furthermore, I wanted to limit the effect that any working memory difficulties would have on the task because deaf children with cochlear implants typically have poorer working memories than their hearing peers (Pisoni & Cleary, 2003). The practice list was derived from the Khanna and Cortese (2009) study, which consisted of 14-word lists written for children reading at a third-grade level. I chose a subset of eight words from each list to match the list length of the target word lists, which were taken unmodified from the Metzger and colleagues (2008) study. These DRM word lists were created to be appropriate for students reading at approximately a second-grade level. These word lists can be found in the Appendix. As mentioned previously, I chose DRM lists with second- or third-grade vocabulary words in order to ensure that the deaf students would not show different effects as a result of unknown vocabulary. As all the students from both the experimental and control groups were reading at least at a fourth-grade level, it can be assumed that differences in vocabulary knowledge of the words contained in the lists were minimal.

The word lists were presented via PowerPoint presentation on a 2011 MacBook Pro laptop set at maximum volume. Each word was presented both visually and auditorily (via audio recording on the PowerPoint) at a 3-second interval. Words were presented bi-modally to ensure that the deaf students did not miss words due to auditory difficulties. Bi-modal presentation of the DRM paradigm was previously used in the Metzger and colleagues (2008) study. An interval of three seconds was chosen to allow the children ample processing time while also keeping the task brief enough to sustain their attention, as previously used in the Holliday and colleagues (2008) study. After the presentation of each list, the students were instructed to use crayons or markers to color a geometric design for 30 seconds. Though a variety of filler tasks as well of the length of those tasks have been reported in the DRM literature, my choice of task was supported by studies by Holiday and colleagues (2008) as well as Howe and colleagues (2009) and my chosen length of interval was used by Hancock and colleagues (2003). After coloring, the students were asked to report all of the words that they could remember from the list in any order. They were given as much time as they needed to try to recall the words. The experimenter recorded the students' answers on a data sheet. Words reported that differed from the targets only in number or tense were counted as correct. For example, *dreaming* was counted as correct for *dream*, and *feet* as correct for *foot*. This procedure was repeated seven times (including a practice list), with the order of presentation of the six target lists counterbalanced across subjects.

Recognition Task. The subjects were presented with a PowerPoint presentation consisting of 108 words. The word list was comprised of the six target lists presented during the recall task (consisting of 48 presented words), the corresponding un-presented critical lures (6 words), six un-presented lists of semantically-related words (48 words), and the corresponding un-presented critical lures (6 words). The un-presented word lists were chosen from the Khanna and Cortese (2009) study. While the lists originally contained 14 words, I again chose a subset of eight words to match the list length of the presented word lists. These word lists can be found in the Appendix. The words were presented in a randomized order. For each word, the experimenter presented the word visually on the computer screen while simultaneously reading the word for the participant. The participants were asked to report "yes" if the word had been presented earlier (during the recall task) and "no" if the word had not been presented earlier. The children were encouraged to answer as quickly and accurately as possible. As soon as the participant reported an answer, the experimenter recorded the answer and proceeded with the subsequent word. This procedure continued until all 108 words were presented.

Category Labeling Task. At the end of the experiment, the children were given a sheet of paper containing each of the six target lists presented during the recall task (not including the practice list) and asked to write a one-word category label for each list. Students were told to try not to use a word from the list as a label and to provide only a single word label if possible. This task was designed to provide additional anecdotal information about the children's categorical knowledge.

Procedure

Each child was tested individually. The testing took place at Washington University School of Medicine or at the child's home. All of the tasks took place in a single session lasting approximately twenty minutes. During the recall and recognition tasks, an experimenter timed the filler task intervals and recorded the child's responses. Parents completed the questionnaire prior to the administration of the experiment. The participants received five Silly Bandz bracelets for taking part in the study.

RESULTS

Recall Task

Table 2 shows the individual data from the recall task and the mean performance of the experimental and control groups. Figure 1 shows the average number of target words recalled by the control and experimental groups. The groups had similar means, with the NH participants recalling only 2.2 more target words on average than the CI users, out of a possible 48 words. Participant CI 5, however, recalled significantly fewer target words than all the other participants in the study, which lowered the average score of the CI group. When CI 5's data are excluded, the average of the CI group increases from 33.0 to 38.0 words. With or without CI 5's data, the means suggest that both groups recalled a similar number of target words during the recall task. Figure 2 shows the average number of critical lures recalled by the CI users and NH participants. While the deaf participants did not have a single false memory (and thus recall a critical lure), the NH participants recalled 1.2 critical lures (out of a possible 6) on average during the recall task.

Recognition Task

Table 3 shows the individual data from the recognition task and the mean performance of the experimental and control groups. Figure 3 shows the average number of target words recognized by the CI users and NH participants. The mean scores of the two groups were quite similar, with the NH participants recognizing on average only 1.7 more words than the CI users, out of a possible 48 words. Again, participant CI 5 had a dramatically different score from all the other participants, only recognizing 30 of the 48 words, and thus affecting the average score of the CI group. Without CI 5's data, the average number of target words recognized by the CI group increases from 39.8 to 42.3. With or without CI 5's data, the NH and CI groups have very comparable mean recognition scores. Figure 4 shows the average number of critical lures recognized by the two groups. On average, the deaf students recognized 27% fewer critical lures than their hearing age-mates.

Category Labeling Task

Table 4 shows the individual responses the participants provided as labels for the lists originally presented during the recall task. All of the participants gave reasonable answers for all of the lists other then CI 5, who provided poor category labels for lists 4, 5, and 6. This suggests that participant CI 5 may not possess the same types of categorical knowledge as the other participants in the study. Almost all of the participants provided the critical lure as a label for lists 1 and 5, while fewer participants used the critical lure as a label for lists 2, 3, 4, and 6.

DISCUSSION

This study aimed to determine whether cochlear implant users organize the vocabulary within their semantic networks similarly to their normally hearing peers. False memories of critical lures indicate a semantic network that has semantic associates organized together in a well-connected manner. The differences between the two groups' mean number of critical lures recalled and recognized during the DRM paradigm suggest that cochlear implant users are in fact organizing their vocabulary in a less efficient and more poorly organized manner than their hearing peers. The implication of poor semantic network organization as a reason for poor vocabulary skills provides an explanation in support of the robust literature documenting the vocabulary deficits usually seen in deaf children, even those with cochlear implants. To my knowledge, this study is the first to document the use of the DRM paradigm to study semantic network organization in deaf children. Further research needs to be conducted with a larger population of deaf students.

Because I could not reliably perform statistical analysis on such a small sample, it cannot be determined whether the differences between the two groups in the number of critical lures recalled and recognized are statistically significant. Comparisons of the two groups, however, do show that the CI users had fewer false memories of critical lures during both the recall and recognition tasks. Deaf children recalled no critical lures during the recall task, while hearing children recalled 1.2 critical lures (out of a possible 6). Deaf children recognized 2.6 critical lures during the recognition task, while hearing children recognized 4.2 critical lures. The small number of participants in this study makes it difficult to draw strong conclusions, but my results suggest that deaf children exhibit fewer false memories when given the DRM paradigm. This supports the hypothesis that deaf children organize their vocabulary in semantic networks in a fundamentally different way from their hearing peers: presumably in a less efficient and less organized manner.

One limitation of the current study is the small number of participants. The small sample size means that each participant's data strongly affected the mean scores of the two groups. Another limitation is that I used parent report of reading level as a proxy for level of vocabulary knowledge. Future studies should use standardized vocabulary test scores to provide better information as to the participants' actual acquired vocabulary skills. An additional limitation is that I was unable to collect data on whether the hearing participants had any known disabilities or whether the deaf participants had any known disabilities in addition to their deafness. Future studies should try to include participants without additional disabilities to ensure that any differences in performance are not due to underlying difficulties in the areas of attention or working memory.

Despite these limitations, the results of this study have important educational implications. Because deaf students typically struggle with vocabulary, it is important to understand the possible underlying reasons for these difficulties. This study offers a potential explanation for these vocabulary deficits: Deaf students may not simply be delayed in their vocabulary skills but may in fact approach the task of learning vocabulary in a fundamentally different manner from their hearing peers. They appear not to situate vocabulary words within the efficiently organized semantic networks that typically hearing individuals exhibit, but rather appear to have networks that do not readily associate semantically-related nodes or have limited connections established between them. If this is the case, and deaf students have vocabulary stored in semantic networks that do not look like those of their typically hearing peers, it would indicate a need for specific educational strategies to help deaf students organize (or reorganize) their vocabulary in more meaningful ways. Although teachers of the deaf currently use strategies to help deaf students to better learn vocabulary, this research suggests that they may need to consider how to teach vocabulary organization and categorical knowledge more explicitly. In the classroom, teachers of the deaf may need to utilize strategies that show deaf students specifically how semantically related words should be associated together and in turn how these groups of words relate to their categorical labels. Future research should consider what educational strategies best improve deaf students' vocabulary abilities and categorical knowledge in order to better inform educational practice.

In the future, I plan to continue to collect data for this study so that I can achieve a large enough sample size to analyze the potentially important differences in semantic network organization of hearing and deaf students. This will better inform the research literature as well as the need for improved educational practices involving vocabulary instruction of cochlear implant users.

References

Carneiro, P., Fernandez, A., Albuquerque, P., & Esteves, F. (2007). Analyzing false memories in children with associative lists specific for their age. *Child Development*, *78*, 1171–1185.

Dewhurst, S. A., & Robinson, C. A. (2004). False memories in children: Evidence for a shift from phonological to semantic associations. *Psychological Science*, *15*, 782–786.

Hancock, T. W., Hicks, J. L., Marsh, R. L., & Ritschel, L. (2003). Measuring the activation level of critical lures in the Deese-Roediger-McDermott paradigm. *American Journal of Psychology*, *116*, 1–14. doi:10.2307/1423332

Hayes, H., Geers, A. E., Treiman, R., & Moog, J. S. (2009). Receptive vocabulary development in deaf children with cochlear implants: Achievement in an intensive auditory-oral educational setting. *Ear and Hearing*, *30*, 128–135. doi:10.1097/AUD.0b013e3181926524

Holliday, R. E., Reyna, V. F., & Brainerd, C. J. (2008). Recall of details never experienced: Effects of age, repetition, and semantic cues. *Cognitive Development*, *23*, 67–78. doi:10.1016/j.cogdev.2007.05.002

Houston, D. M., Carter, A. K., Pisoni, D. B., Kirk, K. I., & Ying, E. A. (2005). Word learning in children following cochlear implantation. *The Volta Review*, *105*, 41–72.

Howe, M. L. (2006). Developmentally invariant dissociations in children’s true and false memories: Not all relatedness is created equal. *Child Development*, *77*, 1112–1123. doi:10.1111/j.1467-8624.2006.00922.x

Howe, M. L., Wimmer, M. C., & Blease, K. (2009). The role of associative strength in children’s false memory illusions. *Memory*, *17*, 8–16. doi:10.1080/09658210802438474

Howe, M. L., Wimmer, M. C., Gagnon, N., & Plumpton, S. (2009). An associative-activation theory of children's and adults' memory illusions. *Journal of Memory and Language, 60*, 229–251. doi:10.1016/j.jml.2008.10.002

Johnson, C., & Goswami, U. (2010). Phonological awareness, vocabulary, and reading in deaf children with cochlear implants. *Journal of Speech, Language, and Hearing Research*, *53*, 237–261. doi:10.1044/1092-4388(2009/08-0139)

Khanna, M. M., & Cortese, M. J. (2009). Children and adults are differentially affected by presentation modality in the DRM paradigm. *Applied Cognitive Psychology*, *23*, 859–877. doi:10.1002/acp.1519

Marschark, M., Convertino, C., McEvoy, C., Masteller, A., McEvoy, Cathy, Convertino, et al. (2004). Organization and use of the mental lexicon by deaf and hearing individuals. *American Annals of the Deaf*, *149*, 51–61. doi:10.1353/aad.2004.0013

Metzger, R. L., Warren, A. R., Shelton, J. T., Price, J., Reed, A. W., & Williams, D. (2008). Do children "DRM" like adults? False memory production in children. *Developmental Psychology*, *44*, 169–181. doi:10.1037/0012-1649.44.1.169

Pisoni, D. B., & Cleary, M. (2003). Measures of working memory span and verbal rehearsal speed in deaf children after cochlear implantation. *Ear and Hearing*, *24*, 106S–20S.

Richgels, D. J. (2004). Theory and research into practice: Paying attention to language. *Reading Research Quarterly*, *39*, 470–477.

Roediger, H. L. III, & McDermott, K. B. (1995). Creating false memories: Remembering words not presented in lists. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21*, 803–814. doi:10.1037/0278-7393.21.4.803

Roediger, H. L. III, Balota, D. A., & Watson, J. M. (2001). Spreading activation and arousal of false memories. In H.L Roediger III, J.S. Nairne, I. Neath, & A.M. Surprenant (Eds.), *The nature of remembering: Essays in honor of Robert G. Crowder*. (pp. 95–115). Washington, DC: American Psychological Association.

Sugrue, K., & Hayne, H. (2006). False memories produced by children and adults in the DRM paradigm. *Applied Cognitive Psychology*, *20,* 625–631. doi:10.1002/acp.1214

Table 1

Characteristics of Participants

Participants	Age (years)	Approximate Reading Level (grade)	Age of Hearing Loss Identification (years)	Age of Cochlear Implantation (years)
CI 1	13.25	6.5	2.50	3.50
CI 2	11.08	5.5	1.50	3.50
CI 3	13.16	4.0	0.00	3.00
CI 4	13.83	11.0	1.08	2.33
CI 5	10.75	5.0	1.00	3.00
Mean	**12.4**	**6.4**	**1.2**	**3.1**
NH 1	13.67	9.0		
NH 2	11.25	7.0		
NH 3	13.58	8.0		
NH 4	11.50	7.0		
NH 5	10.67	6.0		
NH 6	13.00	9.0		
Mean	**12.3**	**7.7**		

Note: CI= Cochlear Implant user; NH= Normally Hearing participant.

Table 2

Individual and mean scores for the Recall Task

Participants	Number of Target Words Recalled (out of 48)	Number of Critical Lures Recalled (out of 6)
CI 1	33	0
CI 2	40	0
CI 3	36	0
CI 4	43	0
CI 5	13	0
Mean	**33.0**	**0.0**
NH 1	43	0
NH 2	33	2
NH 3	30	2
NH 4	32	1
NH 5	33	0
NH 6	40	2
Mean	**35.2**	**1.2**

Note: CI= Cochlear Implant user; NH= Normally Hearing participant.

Table 3

Individual and mean scores for the Recognition Task

Participants	Number of Target Words Recognized (out of 48)	Number of Critical Lures Recognized (out of 6)	Number of Distracter Words Recognized (out of 48)	Number of Distracter Critical Lures Recognized (out of 6)
CI 1	42	2	0	0
CI 2	42	1	0	0
CI 3	42	3	0	0
CI 4	43	5	0	0
CI 5	30	2	1	0
Mean	**39.8**	**2.6**	**0.2**	**0.0**
NH 1	47	4	0	0
NH 2	41	4	0	0
NH 3	37	5	1	0
NH 4	42	4	0	0
NH 5	38	3	1	0
NH 6	44	5	0	0
Mean	**41.5**	**4.2**	**0.3**	**0.0**

Note: CI= Cochlear Implant user; NH= Normally Hearing participant.

Table 4

Individual responses for the Category Labeling Task

Participants	List 1 (fruit)	List 2 (sleep)	List 3 (sweet)	List 4 (foot)	List 5 (car)	List 6 (doctor)
CI 1	fruit	sleep	junk	foot	car	hospital
CI 2	fruits	bedroom	treats	body	car	doctor's office
CI 3	fruit	nighttime	unhealthy	exercise	car	hospital
CI 4	fruits	sleep	sweets	feet	car	hospital
CI 5	fruits	sleepy	candies with sugar	objects	other objects	help get better
NH 1	fruits	sleep	sweets	feet	cars	doctor
NH 2	fruit	sleep	yummy	feet	car	doctor
NH 3	fruit	bed	sweets	human parts	cars	medicine
NH 4	healthy	night	fattening	useful	cars	doctors office
NH 5	fruit	bedtime	junk food	feet	car	doctor
NH 6	fruit	bedtime	sweet	feet things	car	hospital

Note: CI= Cochlear Implant user; NH= Normally Hearing participant.

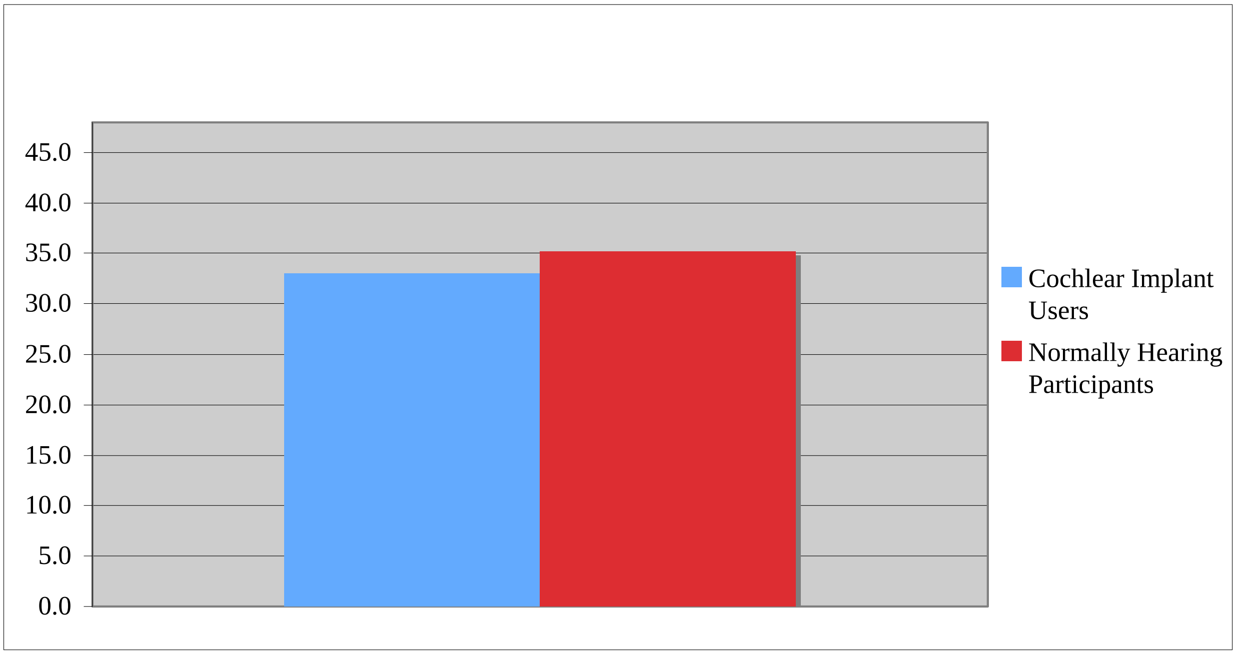

Figure 1. Average number of target words recalled.

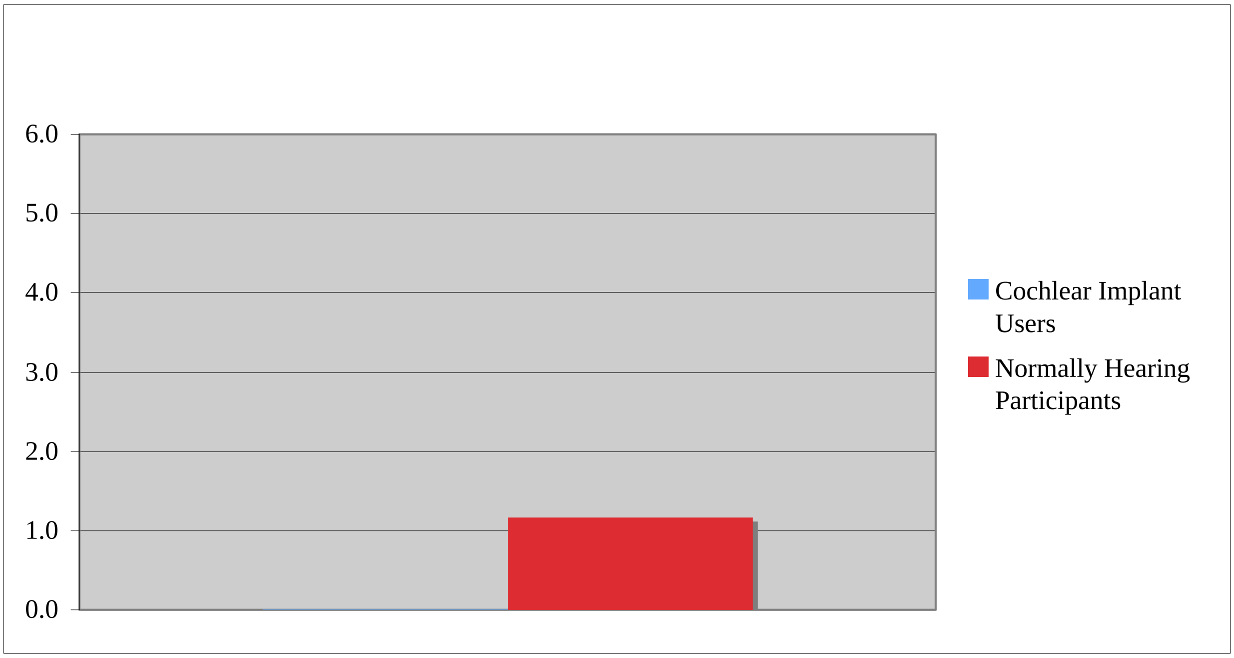

Figure 2. Average number of critical lures recalled.

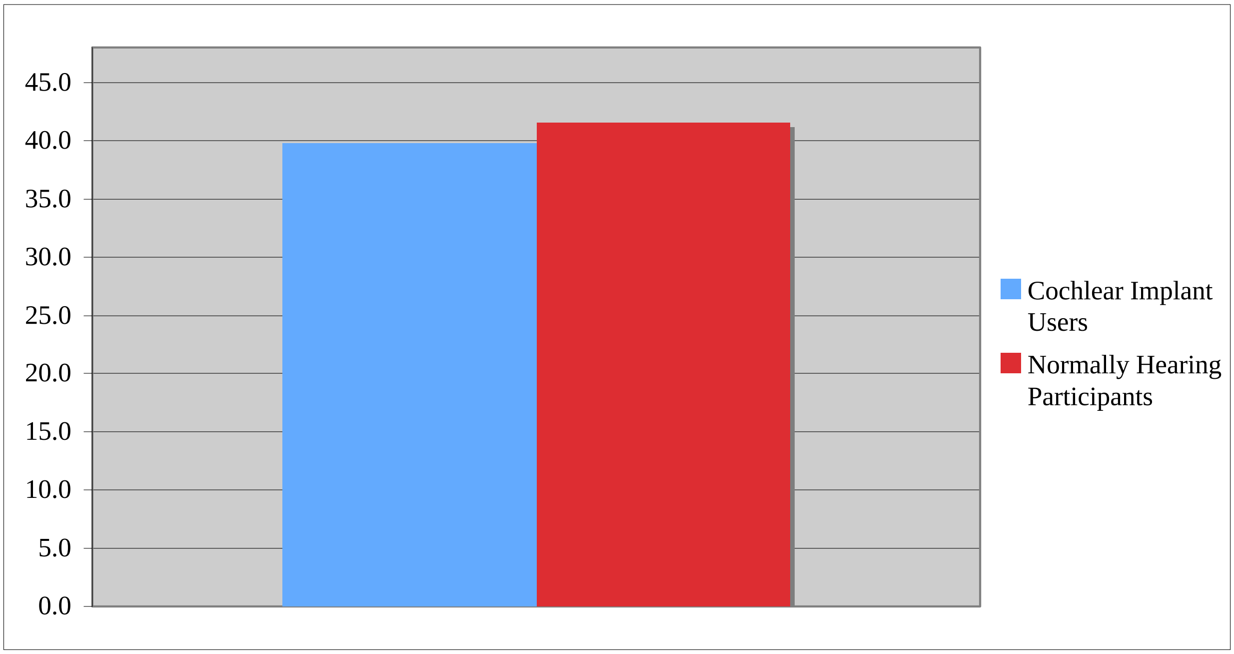

Figure 3. Average number of target words recognized.

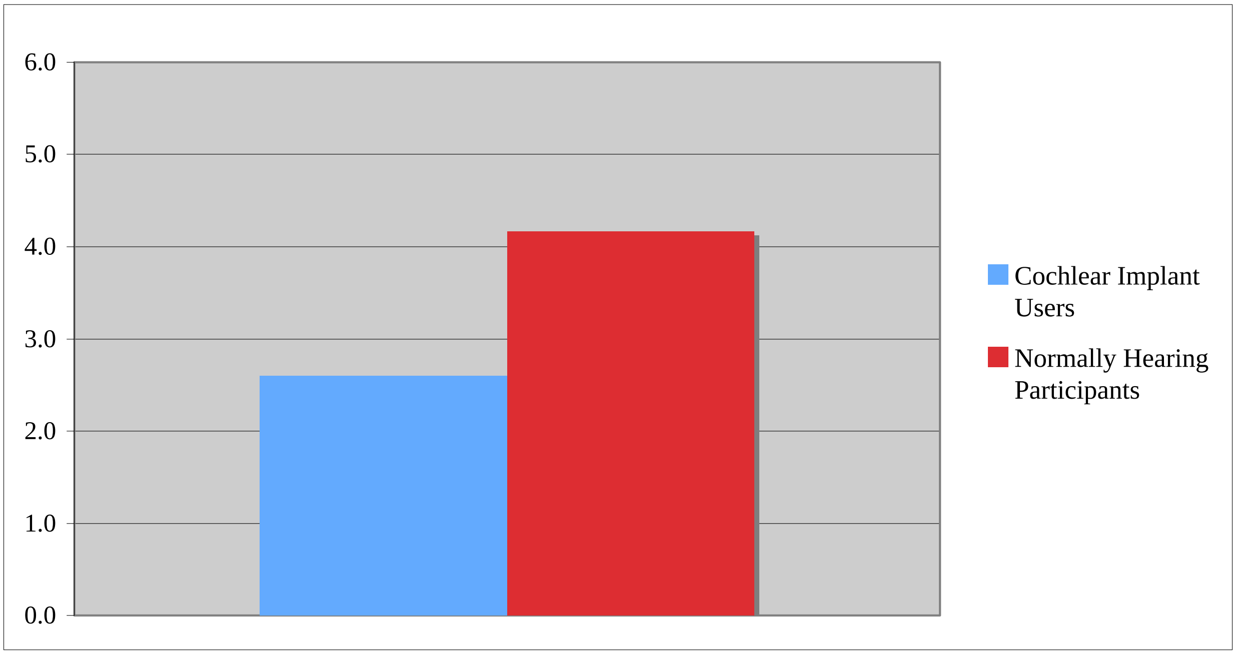

Figure 4. Average number of critical lures recognized.

Appendix

Practice List (derived from Khanna & Cortese, 2009)

Critical Lure	Items
cat	meow, fluffy, kitten, claw, stray, cougar, mouse, tiger

Presented Lists (used unmodified from Metzger et al., 2008)

Critical Lure	Items
fruit	apple, orange, banana, food, grape, strawberry, pear, juice
sleep	bed, pillow, dream, covers, night, tired, nap, sheets
sweet	candy, sugar, chocolate, ice cream, taste, nice, sour, cookies
foot	toes, shoes, walking, socks, jumping, ankle, leg, running
car	wheel, gas, window, radio, seat, engine, steering, drive
doctor	nurse, shot, medicine, checkup, surgery, patient, sick, help

Un-presented Lists (derived from Khanna & Cortese, 2009)

Critical Lure	Items
dog	puppy, mutt, wolf, beware, bark, animal, poodle, flea
cold	chill, warm, hot, winter, sneeze, freezer, snow, cool
hit	slap, spank, miss, kick, bump, fist, knock, whip
back	behind, side, front, rear, pack, yard, spine, forward
rain	umbrella, storm, wet, puddle, thunder, wind, water, weather
chair	table, sit, wood, bench, desk, stool, lawn, furniture