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NOVEL WORD-LEARNING FOR NORMAL-HEARING AND HEARING-IMPAIRED CHILDREN

by

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An Independent Study
submitted in partial fulfillment of the requirements for the degree of:

Master of Science in Deaf Education

Washington University School of Medicine
Program in Audiology and Communication Sciences

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Approved by:
Lisa S. Davidson, Ph.D., Independent Study Advisor

Abstract: The study was designed to determine the appropriateness of a novel word-learning paradigm for normal-hearing and hearing-impaired children as well as to explore the nature of word-learning abilities for both groups. Pilot data was gathered to determine the number of words learned following separate intervals and throughout the test session.

Introduction and Background:

Language acquisition by normal hearing children occurs naturally, effortlessly, and instinctively among a variety of other sensory and intellectual experiences. It involves the development of linguistic knowledge resulting from the distributional analysis of aspects of the stimuli including vowel space, consonant categories, phonotactic rules, phonological regularities, and frequent biphones (Saffran, Newport, Aslin, Tunick, &Barrueco, 1997). The underlying psychological processes which facilitate speech perception, lead to word recognition and comprehension, and ultimately result in spoken language competence are not completely understood, but normal-hearing children demonstrate proficiency simply by "over hearing" language.

Studies have shown that as early as 6-8 months infants are able to discriminate sounds phonetically (Werker & Tees 1992). Following the ability to extract words from the speech stream, infants ages 10-12 demonstrate proficiency in recognizing phonemic contrasts (Pegg & Werker 1997). By the end of the first year of life, children become skilled in their ability to map meaning onto sound and are well on their way to developing language (Stager & Werker, 1997).

Children demonstrate the ability to rapidly acquire words in both experimental and natural settings, and a number of proposed strategies and underlying factors have been presented to explain word learning among children. In some instances this learning takes place in the absence of numerous cues which assist with form-referent matching. This phenomenon has been referred to as *incidental* learning and is supported by the work of Saffran et al. (1997) in a word segmentation task. Subjects included a group of normal-hearing children (age 6-7) and a group of college-age adults. All subjects listened to a synthetically produced speech stream presented via a 21-minute audiotape consisting of 300 tokens of each of six trisyllabic nonsense words. No

pauses were present, and the only cues to word boundaries were the transitional probabilities between syllables. While the tape was playing, all subjects were engaged in a diversion task and were given no instruction to listen to the "words" being presented. Six nonwords to be used as foils were created by combining syllables in sequences that never occurred during the exposure period. In a 36-item forced-choice test, the nonwords were exhaustively paired with the nonsense words from the audiotape. Adults and children performed similarly; the mean scores for both groups were above chance. These results suggest that the computation of transitional possibilities can occur incidentally and therefore may underlie natural learning.

A number of proposed strategies and underlying factors have been presented to explain word learning among children. Novel word learning is one such strategy. This type of learning refers to the ability to acquire the meaning of new vocabulary through limited exposure to a word and without the use of specific instruction and has been demonstrated in normal-hearing children as young as 15-18 months of age (Oetting, Rice, & Swank, 1995). In the study of novel word learning, the terms "fast mapping" (Carey, 1978) or "quick incidental learning" (Rice, Buhr, & Nemeth, 1990) are sometimes used to describe the ability to learn a new word in a related context within the first few exposures and without direct instruction. Word learning occurs at a staggering rate for children; they begin learning words at about age one and by the time they graduate from high school they have developed a vocabulary of about 60,000 words (Bloom, 2000). The rate of learning, however, its not constant and the ability to infer meaning from unfamiliar words in context seems to appear when a vocabulary size of approximately 200 words is reached (Evey & Merriman 1998).

Due to the implementation of newborn hearing screenings, early identification and intervention services are available to many hearing-impaired children. The result is that many

deaf children are now receiving sensory devices that provide amplification at ages that more closely coincide with critical periods of language development. The overall goal of amplification is not only to make speech audible but to facilitate language learning, and as yet it is unclear how advancements in sensory devices will affect the performance of hearing-impaired children in comparison to their normal-hearing peers (Stlemachowicz, Pittman, Hoover, & Lewis, 2004). Studies have tried to determine the ways in which a hearing impairment can affect word-learning and which, if any, of a number of other variables might contribute.

In a comparison of novel word learning abilities among normal-hearing children and those with a mild to moderate loss using hearing aids, Gilbertson and Kamhi (1995) found that the hearing-impaired group required more trials in order for novel word learning to occur. Stelmachowicz et al. (2004) examined the word learning abilities of 20 normal-hearing and 11 hearing-impaired children ages 6-9 year. The children were presented with 8 novel words throughout the course of a 4-minute animated story. After two presentations, a forced-choice identification task was administered. The study was designed to evaluate the effects of word form (noun vs. verb), presentation level (50 vs. 60 dB SPL) and number of repetitions (4 vs.6). Results indicated a greater mean performance level for the normal-hearing compared to the hearing-impaired children (60% vs. 40% of the novel words correctly identified). In addition to hearing status, performance on the Peabody Picture Vocabulary Test proved to be a significant predictor of success (Stelmachowicz et. al. 2004).

Lederberg, Prezbindowski, and Spencer (2000) designed a study which included only hearing-impaired children. While they investigated the development and use of novel mapping strategy in the presence of a discrepancy between language skills and cognitive ability, their study did not specifically address word acquisition through the use of audition alone. The

subjects included 19 deaf preschoolers with an age range of 3.2 to 6.10 years. In the novel mapping test, the children were presented with two types of objects, familiar and novel. Labels for each type of object were simultaneously signed and spoken, though no direct instruction of the words took place. The children were then asked to select the referent of both a nonsense word and a familiar word from three objects displayed in front of them. In the rapid word learning task the same procedure was followed, but instruction was explicit with each object being labeled three times. The children were followed longitudinally in the study, and results indicated a link between word-learning abilities and vocabulary size. The children with the smallest expressive and receptive vocabulary as determined by the *MacArthur Communication Development Inventory (CDI)-words and sentences version* did not learn new words under either condition, while those with the largest vocabulary were successful on both the rapid word learning task and the novel mapping task. The researchers explain that while normal-hearing and hearing-impaired children may possess similar cognitive abilities as exhibited by categorization skills, these results suggest that a "specific linguistic process" causes the emergence of the novel mapping strategy.

A more recent study (Pittman, Lewis, Hoover, & Stelmachowicz, in press) tested 60 children with normal-hearing and 37 children with moderate sensorineural hearing losses, all ranging in age from 5 to 13. Eight novel words were introduced within the context of a 4-minute story that was presented two times. Half of the eight words were low-pass filtered at 4kHz and half were filtered at 9kHz. Each word was repeated on three different occasions throughout the course of the story. Following the second presentation of the story, an identification task was administered. The children were asked to tap a touch-screen monitor to identify the picture that corresponded to the word presented. Each word was presented 10 times and performance was

calculated after every 10 trials over an 80-trial series. The extended high-frequency bandwidth did not significantly improve word-learning for either group, nor was an increase in performance observed as the test progressed for any group of children. In fact the youngest hearing-impaired group showed a decrease in performance despite feedback on every trial (Pittman et al., in press).

In addition to vocabulary size, other variables appear to play a role in word-learning ability including working memory span, internal verbal rehearsal, and the mapping of phonological representations to word meanings (Houston, Carter, Pisoni, Kirk, & Ying, 2002). The focus of a number of studies has been the effects of working memory. Working memory is usually defined as a temporary storage mechanism for holding in conscious awareness, information obtained from perception or retrieved from long-term memory (Baddeley & Hitch 1974). Working memory has traditionally been assessed using digit span measures. The CID cochlear implant study by Pisoni and Geers (2000) contained a total of 176 subjects, both normal-hearing children and cochlear implant users. A strong positive correlation between verbal digit span and language development was reported, with a longer digit span evidenced among the normal-hearing compared to the children with severe-profound hearing loss.

Pisoni hypothesized that a greater use of internal verbal rehearsal was a contributing factor in the digit span study results (Pisoni, 2000). Verbal rehearsal refers to the simple vocal repetition of verbal materials to be remembered. In the analysis of data from an earlier study of cochlear implant subjects, Pisoni and Cleary (2003) explain how verbal rehearsal might account for increased word learning. By nature a spoken word extends temporally in time. This means that information received early in the signal must be retained while the remainder of the utterance is listened to and processed. Pisoni and Cleary propose that verbal rehearsal is likely

the processing mechanism which allows for maintenance of the representation as a response is generated.

Yet another variable thought to affect word-learning involves discrimination among lexical items. Based on previous research showing that words vary in the number of words to which they are similar and also in the frequency of these similar words, Luce and Pisoni (1998) developed the concept of neighborhood similarity to describe a collection of words that are phonetically similar to a given stimulus word. Based on the results of their study, the Neighborhood Activation Model (NAM) was developed. In this model, words are categorized as high or low-frequency, and within these categories they are then assigned to a high or low-frequency neighborhood (referring to the frequency of neighbors) and a high or low-neighborhood density (which considers the number and degree of confusability of words in the neighborhood).

Findings presented by Luce and Pisoni (1998) reveal that, in general, high-frequency words are more easily and accurately classified than low-frequency words. Among these words, some words fall into high-density neighborhoods which refers to the number of lexical neighbors that a word has. These words are classified more slowly but more accurately than words in low-density neighborhoods. Words are also classified according to neighborhood frequency. This refers to the average word frequency of a target word's lexical neighbors. Low-frequency neighborhoods allow for quicker and more accurate classification than high-frequency neighborhoods (Kirk, Pisoni, & Osberger, 1995).

Probabilistic phonotactics refers to the relative frequency of segments and sequences of segments in syllables or words. A word or nonword is said to have high phonotactic probability if it contains sequences of phonemes that occur in the same order and position as many other

words. Conversely, a word or nonword with low phonotactic probability contains phoneme sequences that occur rarely across words. A positive correlation has been determined between phonotactic probability and neighborhood density with the results indicating that words with high phonotactic probability typically occur in dense phonological neighborhoods while words with low phonotactic probability occur in sparse phonological neighborhoods (Vitevitch, Luce, Pisoni, & Auer, 1999). While the NAM model has proven reliable in predicting recognition speed and accuracy for real words, a discrepancy seems to occur in the processing of nonwords; high probability words were responded to more, rather than less, quickly (Vitevich, Luce, Charles-Luce, & Kemmerer, 1997). It is hypothesized that the nonwords, while triggering phonetic recognition, have the advantage of failing to strongly activate competing lexical representations (Vitevich et al. 1999).

The potential for phonotactic probability to influence word learning is a subject of growing interest. Evidence has shown a correlation between nonword repetition performance and lexical development (Gathercole, Willis, Baddeley, & Emslie, 1994). In an experiment designed to study the influence of phonotactic probability on novel word learning, Storkel selected thirty-four children ranging in age from 3 years 2 months to 6 years 3 months to participate in a multi-trial word-learning task. Nonsense words ranging from common to rare based upon phonotactic probability were paired with unfamiliar objects. Form and referent learning were tested following 1, 4, and 7 exposures, as well as after a one-week delay. Results indicated that common sound sequences were learned more rapidly than rare sound sequences across form and referent learning (Storkel, 2001).

Aim of Study:

The purpose of this study was twofold. The first purpose was to determine the appropriateness of the novel word-learning paradigm for hearing-impaired and normal-hearing 5 and 6 year olds. The second purpose was to explore the nature of word-learning ability for hearing-impaired children and normal-hearing children. In addition, pilot data was gathered to determine the number of words learned following each interval of a story as well as the overall number of words learned across the duration of the session. Results were analyzed in order to make decisions regarding future test methods and measures.

Method:

Subjects:

Five normal-hearing and five hearing-impaired children were included in the study. The normal-hearing children had an average age of 5 years 1 month with a range from 4 years, 7 months to 5 years 10 months. The hearing-impaired children had an average age of 5 years 10 months, with specific ages ranging from 5 years 5 months to 6 years 3 months.

All of the hearing students passed a hearing screening. Among the normal-hearing subjects, two attended the oral preschool at CID, one was enrolled in a regular preschool, one was enrolled in a regular education kindergarten class, and one received home day care.

All hearing-impaired students were enrolled in an oral program at Central Institute for the Deaf. Three children were fitted binaurally with hearing aids, and two of the students had cochlear implants. The three children using bilateral hearing aids had losses in the moderate to profound range with an average unaided puretone average threshold (PTA) at .5, 1, and 2kHz in the better ear of 79 dB HL. One child with a unilateral cochlear implant had pre-implant

thresholds in the profound range with PTA's of 115 dB HL in both ears. The final hearing-impaired subject had a pre-implant PTA of 98 dB HL in the left ear, and an unaided PTA of 82 dB HL in the hearing aid ear.

The aided thresholds for the hearing aid children ranged from 15 to 95 dbHL across the frequency range of 250 through 4000 Hz. The children with the cochlear implants both had aided thresholds at 30 dB HLor better from 250-4000 HZ.

Test Equipment:

The novel word test was performed in a single walled booth using a GSJ61 audiometer and a loud speaker. The story and word stimuli were presented via an IBM R40 ThinkPad laptop computer.

Test Procedures:

The *Peabody Picture Vocabulary Test* was administered to each subject no longer than six months prior to the start of the study. Results are displayed in Table 1. While all tests were scored following standard procedure, raw scores were considered in order to estimate the receptive vocabulary of each child. Raw scores were used to provide an independent variable which would reflect the relation between age and vocabulary for both groups. It is important to note, however, that raw scores indicate the number of words within the test that were familiar to the child and are typically converted to standard scores for evaluative use. This procedure is consistent with the study designed by Stelmachowicz et al. (2004) which found PPVT raw scores to be a significant predictor of performance.

Word-Learning Paradigm

Eight CVCVC nonsense words were created. Each word's phonotactic probability was determined through use of The Phonotactic Probability Calculator (Vitevich & Luce, 2004)

which employs a database and an algorithm to determine the phonotactic probability of words based on positional segment frequency and biphone frequency. Positional segment frequency refers to how often a particular segment occurs in a certain position in a word, and biphone frequency calculates the segment-to-segment co-occurrence probability of sounds. The sum of all phoneme position probabilities and the sum of all biphones probabilities were calculated. Vitevich suggests that by ordering the sums of each of the nonwords and taking the mean one can determine the operational phonotactic probability of the words. Those nonwords with sums greater than the median value for measures of phoneme and biphones probability are operationally defined as having high phonotactic probability, while those whose sums are less than the mean are considered to have low phonotactic probability (Vitevich & Luce, 2004). None of the phonemes occurred in positions contrary to the English language. The pictures, words, and their phonotactic probabilities are displayed in Table 2.

A story consisting of 6 distinct scenes was created. Each scene focused on the main character, a bear, viewing his newly received birthday gifts in different surroundings. Scenes from a children's book (Bennett and Kightley) were combined and adapted to incorporate pictures of uncommon toys obtained from clip art into a Microsoft PowerPoint presentation. A narrative was created to accompany each scene as the main character, Teddy, visited his friends to look for help in deciding which new toy to play with first. The story is contained in Appendix A. The pictures of each uncommon toy faded in and out on the screen for a three-second interval as they were named by the narrator within the context of a sentence. Each of the four items was presented one time during each of the six scenes. The order of presentation of each word and object was initially randomized but then presented consistently for each subject. All children were tested in a single-walled sound booth in the Pediatric Audiology Department at CID. The

children were positioned at 0° azmuth from a loudspeaker. The story and all test words were read by a female talker with experience teaching deaf children. Speech was recorded at a sampling rate of 22.05 kHz using an Audio-Technica ATM75 headworn microphone and an external Roland UA-30 USB audio interface device. The story was divided into paragraph segments, ranging in length from 7 to 12 sentences. After recording, each paragraph-segment was trimmed, as needed, and then normalized in overall rms-level to match the rms-level of a calibration warble tone. The warble tone was set and calibrated via the audiometer prior to the start of each test session to produce a sound level at the approximate location of the listener's head of 60 dB SPL.

The children were told they would hear a story that had words they had not heard before and pictures of toys they had not seen before. They were told that after a short time the story would stop and they would hear a word and be asked to point to the picture that was named. As in previous studies (Pittman, Lewis, Hoover, & Stelmachowicz, in press), it was decided that a direct approach would prevent the children from incorrectly focusing their attention on some other aspect of the story.

Following each of the six story segments, a 16 item four-choice closed-set picture test was administered in order to analyze performance following each interval. In addition the scores were collapsed across all six segments to obtain an overall number correct out of 24 presentations for each target nonword as well as a total number correct out of 96 total presentations. Each picture card consisted of the target word picture and three other pictures. Two of the alternative pictures were pictures of other nonwords presented in the story, and the third alternative picture was one of three foils not presented in the story. In the test, the child was presented with a recorded target nonword and asked to select the corresponding referent

from the field of four pictures. A word was considered correctly identified for a given test sequence if it was chosen 3 of 4 times during a specific test session.

Results:

The normal-hearing children obtained an average performance level across the total 96 presentations of 32% for the word identification task, while the average performance for the hearing-impaired children was 27%. The performance level of each group after each of the 6 trials was recorded. The results are displayed in Table 3.

Individual scores were recorded for each word after each of the six intervals to examine the effect of repeated exposures on the rate of novel word-learning. Graphs 1-10 show the rate of learning across sessions for each subject.

Data was collapsed to determine a total number of correct responses for each of the four words across the six test sessions. A score of 8 correct out of the 24 exposures was considered above chance (six correct answers would indicate performance at chance level) and taken to indicate that a word had been learned. The total number of words learned by the normal-hearing and the hearing-impaired children are displayed in Table 4. All subjects learned at least one word. Only one of the hearing-impaired children learned 2 words, and none learned more than 2. Three of the five normal-hearing children learned 2 or more words.

Percentage of correct answers was computed for each novel word in order to determine the most- and least-learned words. These numbers were compared with the phonotactic probability statistics of each word. Table 5 shows these results. The most-learned word for the hearing-impaired group possessed the highest biphone sum. This result is consistent with the findings of Vitevich et al. (1997) that high probability nonwords are learned more readily. The

trend, however, is not present among the normal-hearing group nor does it evidence itself across all words; the second highest biphone sum did not correlate with the second most-learned word.

Summary and Conclusions:

Group Results:

Overall, the normal-hearing children performed better than the hearing-impaired children. The results of this pilot study revealed an overall appropriateness of the word-learning paradigm. All children were able to learn at least one novel word over the course of the testing period. This finding is consistent with other studies involving both normal-hearing and hearing-impaired children.

Rate of Learning:

With regard to rate of learning, it was hypothesized that the children would demonstrate improved performance with repeated exposures to the novel words. While this was clearly the case for some subjects, others had scores that either declined or peaked and then declined across the test sessions. In addition, some children demonstrated a decline in performance on one word when mastery of another word was emerging.

Results for the hearing-impaired group demonstrated a decline in performance percentage at the final test session. While a trend for scores to decrease with repeated exposures was seen among the hearing-impaired subjects in this study as well in the study conducted by Pittman et al. (in press, 2005), more repetitions of each word per story segment might have a different effect.

PPVT Scores:

Higher PPVT scores did seem to correlate with a greater number of words learned for some of the subjects as shown in Table 6. It was noted by the test administrator that those children with higher PPVT scores who did not learn more than one word demonstrated lack of motivation and attention over the course of the test sessions.

Additionally, some subjects were observed repeating words out loud following presentation by the speaker. These students all learned more than one word across the 6 test sessions. This observation is in keeping with the findings of Pisoni and Cleary (2003) that verbal rehearsal may contribute to increased word-learning.

Future Considerations:

Because new factors affecting word-learning continue to be discovered, it is not possible to determine the precise aspects of this study which may have contributed to the results; however several adjustments to future study design might be considered. Fatigue and boredom appeared to be contributing factors for at least some of the subjects. Reinforcement during the test sessions might be added in future testing, though no definitive effect of such has been reported in other studies (Pittman et al., in press). Increased subject interaction with the story or test procedure could also be devised in an attempt to improve motivation. Additionally, a short break might be included after the third story segment. Finally, the overall number of story segments might be decreased.

Further investigation of the contribution of phonotactic probabilities could be pursued in future studies. Two sets of words, those with high phonotactic probability and those with low phonotactic probability, could be presented to determine if a trend for learning nonsense words with high phonotactic probability is revealed. Whatever particular modifications are

implemented, a larger subject sample is definitely required if more definitive statements about novel word-learning are to be made.

Appendix A

Teddy's Birthday Surprise

Slide 1:

Teddy woke up on his birthday feeling very excited. His mom and dad had promised him a big surprise. Teddy's mom told him to go outside and he would see all of his birthday presents. Teddy ran outside, and he could not believe what he saw! There in his yard was a *roogoch*. Next he spotted a t*eevel*. After that Teddy saw a *haycone*, and the last new toy he saw was a *nowize*.

Slide 2:

Teddy was so excited about his new toys that he didn't know which one to play with first. He wanted to show his toys to all of his friends and ask them for their help. Teddy asked his mom if he could go see his friends. She said, "Yes," so Teddy ran off to find his friends.

Teddy ran all the way to the pond to see his friend Froggy. When Froggy saw Teddy, he hopped out to say hello. Teddy told Froggy that he had just gotten some new toys and he didn't know which one to play with first. Froggy said that he would try to help. First Teddy held up the *teevel.* Next he showed Froggy the *haycone*, and then the *nowize*. When Teddy showed Froggy his last present, the *roogoch*, Froggy jumped up and shouted that was his favorite. Teddy said thank you to Froggy and went off to visit some more friends.

Slide 3:

Teddy's next stop was the jungle. Chimp and Champ, his monkey friends, were busy swinging from the trees. Teddy stood on the ground and looked up at his friends. He asked them if they could help him pick a toy to play with, and they said yes. Teddy held up his toys one at a time so Chimp and Champ could see them. They liked the *nowise* that Teddy showed them first. They also liked the *haycone*, and then the *teevel* that Teddy held up. But they clapped their hands and cheered when they saw the *roogoch*. They said that would be the most fun to play with. Teddy thanked Chimp and Champ and said goodbye.

Slide 4:

Teddy walked for a long time to find his friend Lumpy. Lumpy was taking a walk in the sand, but he was happy to stop to look at Teddy's birthday presents. Lumpy said that he liked the *teevel* that Teddy showed him first. He also liked the *nowize*, and he even thought the *roogoch*,was really neat. But when Lumpy saw the *haycone*, he said that would be the best thing to have in the desert. Teddy was glad that Lumpy liked his toys, but everyone was telling him to pick a different toy. Teddy still did not know what to do.

Slide 5:

Teddy knew that if he really wanted to get some help he would have to find his last two friends. He jumped on a sled and slid over the ice. Teddy stopped near the lake and put his toys next to the water hole so that Wally could jump out of the water to see them. Wally looked at each toy carefully. First Teddy showed Wally the *nowize*, and then he held up the *roogoch*. Next Wally looked at the *teevel*, and finally Teddy showed him the *haycone*. Wally said that all the toys were really nice but that he had to swim down to catch a fish so he couldn't help Teddy pick which one to play with first.
Teddy knew that Wally needed to eat, so he said goodbye.

Slide 6:

Teddy was getting tired, but he had one more friend to talk to. He got back on his sled and went up the mountain to see his very best friend of all, Poley. Poley was just getting ready to take a nap, but he said he would look at Teddy's presents before he went to sleep. Poley looked at the beautiful toys thatTeddy put on the snow in front of him. Teddy was a very lucky bear. His mom and dad had gotten him a *roogoch*, ----a *teevel*,---- a *haycone*,---- and a *nowize*! Poley told Teddy that every present was great and that he should go home and say thank you to his mom and dad.

Conclusion:

Teddy thought about what Poley had said and decided it wasn't important which toy he played with first. He could play with any of his toys any time that he wanted. What was really important was for Teddy to tell his mom and dad how much he liked his presents.

Teddy got home as fast as he could. He ran into the house and gave his mom and dad a big bear hug. He said, "Thank you very much mom and dad. This was the best birthday ever!"

Table 1

Peabody Picture Vocabulary Test					
Subject	**Device**	**Unaided PTA dB HL**	**Aided PTA dB HL**	**Age at test** years:months	**PPVT III Raw Score**
NH-1				5:6	58
NH-2				4:7	83
NH-3				5:2	77
NH-4				5:10	101
NH-5				5:1	88
HI-1	Bilateral hearing aids	92	40	5:9	43
HI-2	Bilateral hearing aids	87	27	6:2	30
HI-3	Unilateral Cochlear implant	Pre-implant 115	27	6:2	73
HI-4	Cochlear implant-left ear Hearing aid-right ear	Pre-implant 98 right ear 82	Implant 21 h.a. 35	6:3	26
HI-5	Bilateral hearing aids	58	22	5:4	49

Table 2

Novel Word	Picture	Sum Biphone
Roogoch		0.0027
Teevel		0.0060
Haycone		0.0052
Nowize		0.0049

Table 3

Average percent correct following each scene						
	Scene 1	**Scene 2**	**Scene 3**	**Scene 4**	**Scene 5**	**Scene 6**
Normal-hearing	29%	18%	33%	31%	46%	45%
Hearing-impaired	21%	33%	29%	30%	31%	24%

Table 4

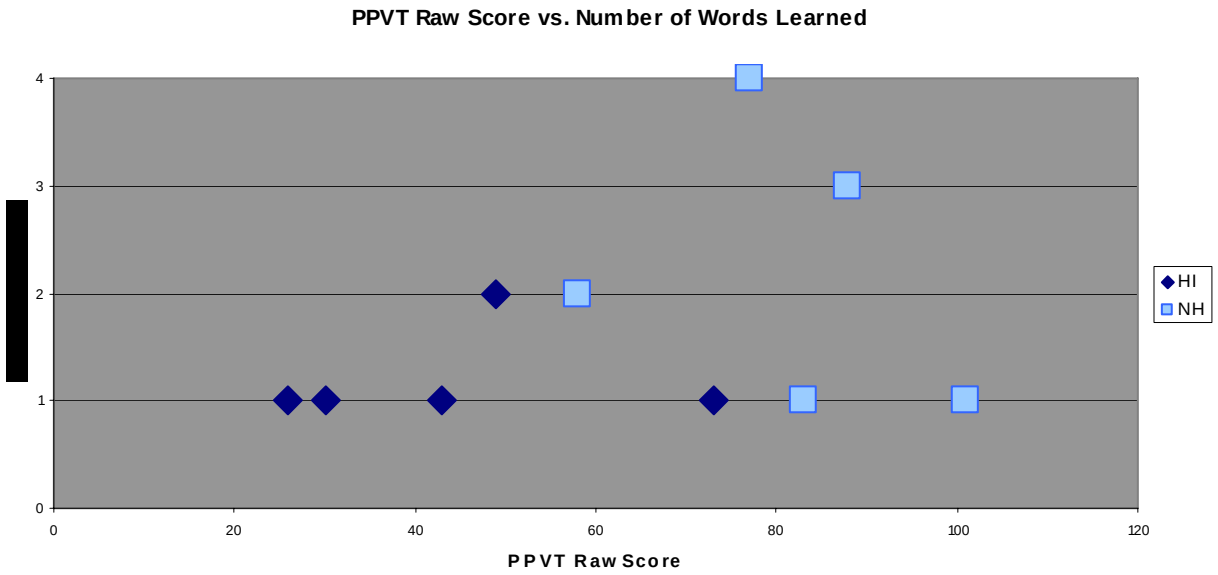
Total Number of Words Learned					
	Subject 1	**Subject 2**	**Subject 3**	**Subject 4**	**Subject 5**
Normal-hearing	3	4	2	1	1
Hearing-impaired	1	2	1	1	1

Table 5

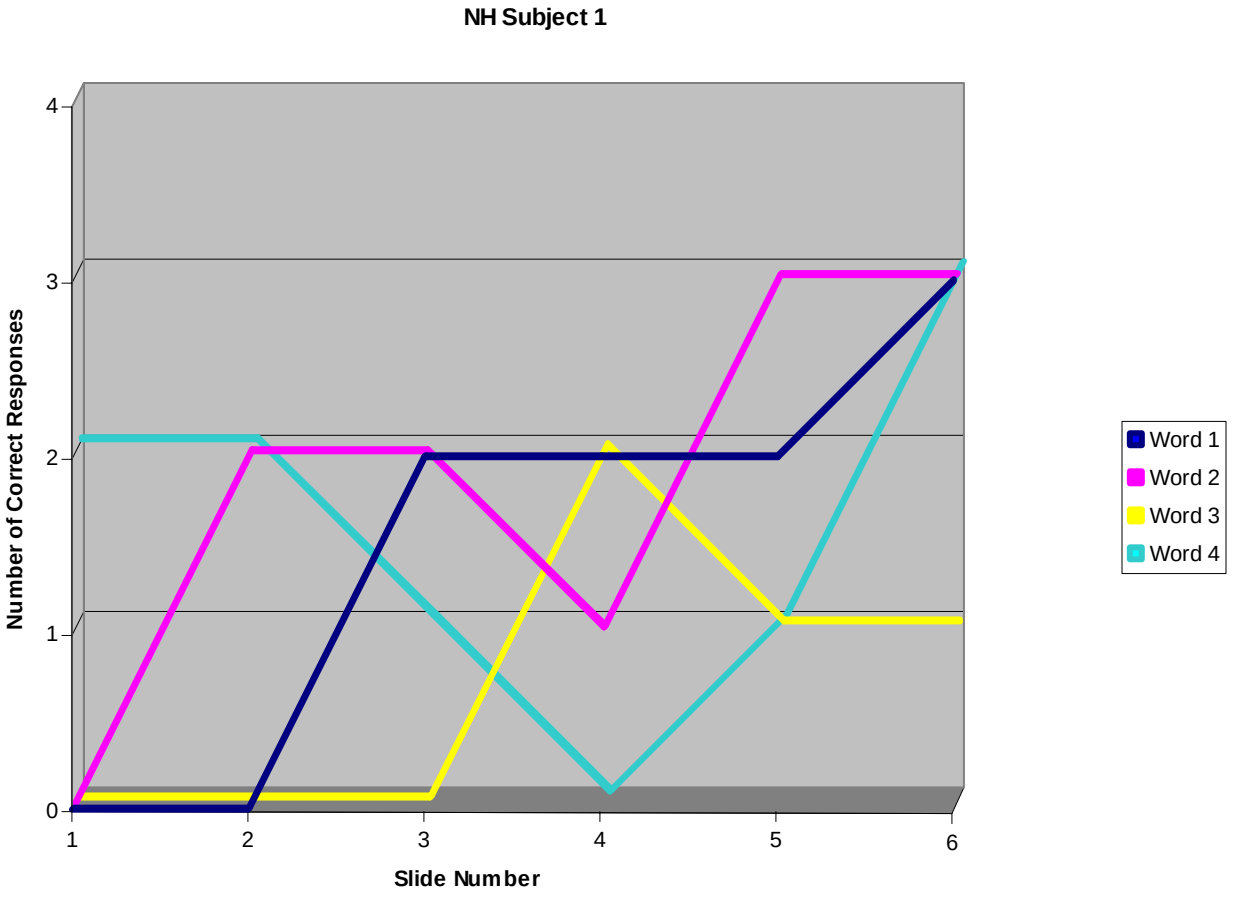
Phonotactic Probability in Relation to Word-learning Percentages			
Word	**Biphone Sum**	**Percent Correct Normal-Hearing Subjects**	**Percent Correct Hearing-Impaired Subjects**
Roogoch	.0027	**37%**	32%
Teevel	**.0060**	35%	**37%**
Haycone	.0052	30%	23%
Nowize	.0049	28%	16%

* Highest numbers in each category are bolded

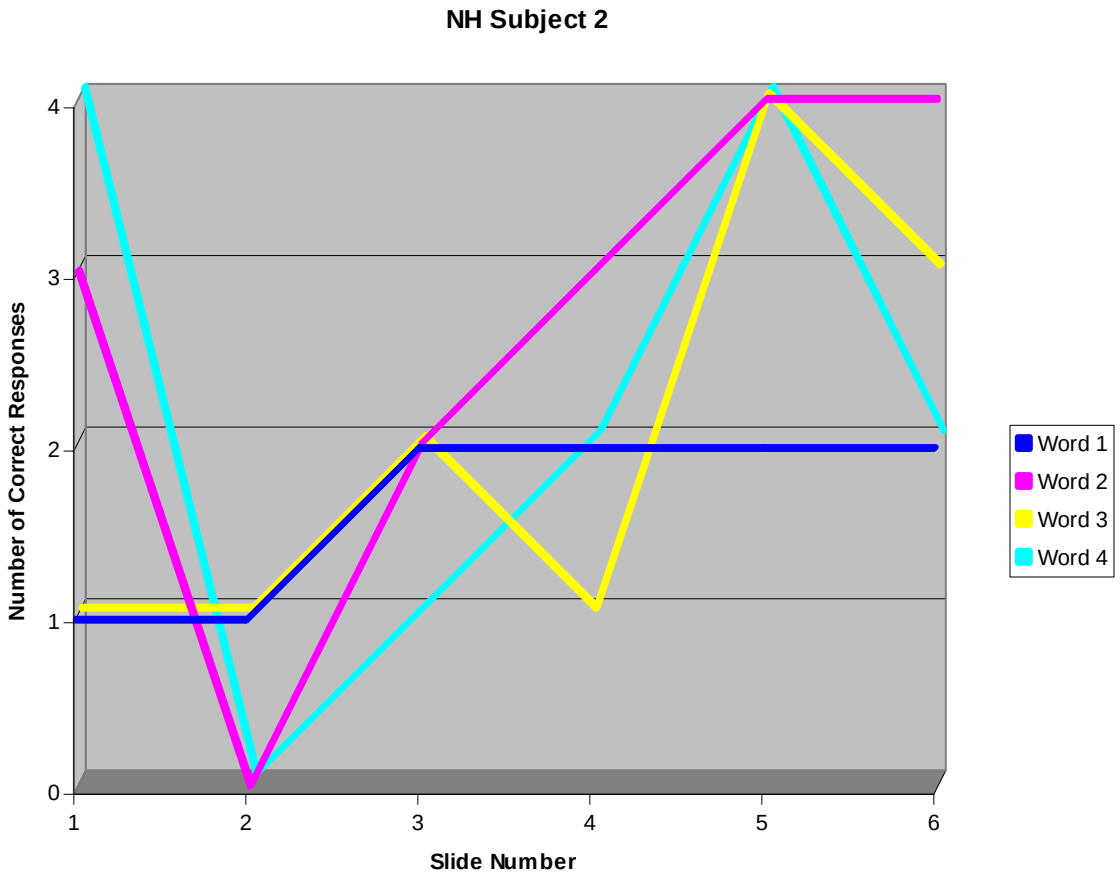
Table 6


PPVT Raw Score vs. Number of Words Learned
4
3
2
1
0
0
20
40
60
80
100
120
PPVT Raw Score
HI
NH

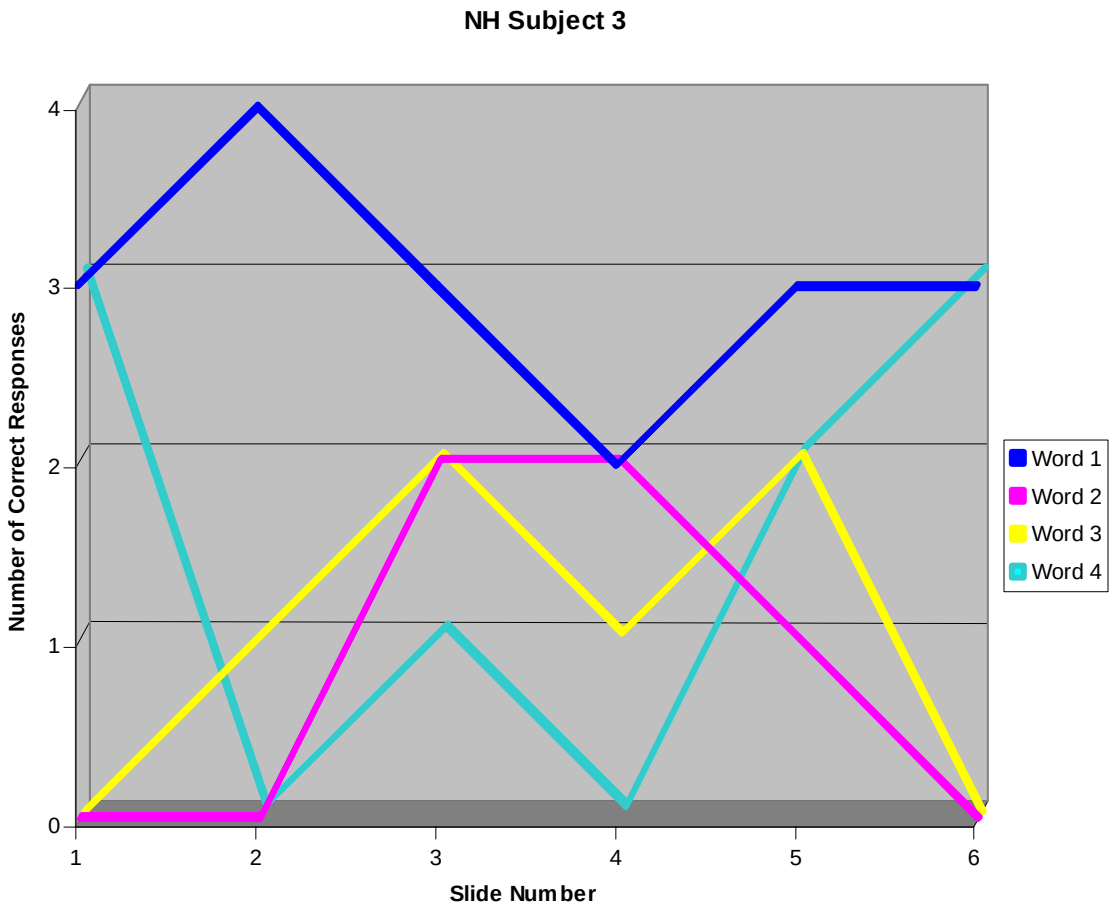
Graph 1


NH Subject 1
Number of Correct Responses
0
1
2
3
4
1
2
3
4
5
6
Slide Number
Word 1
Word 2
Word 3
Word 4

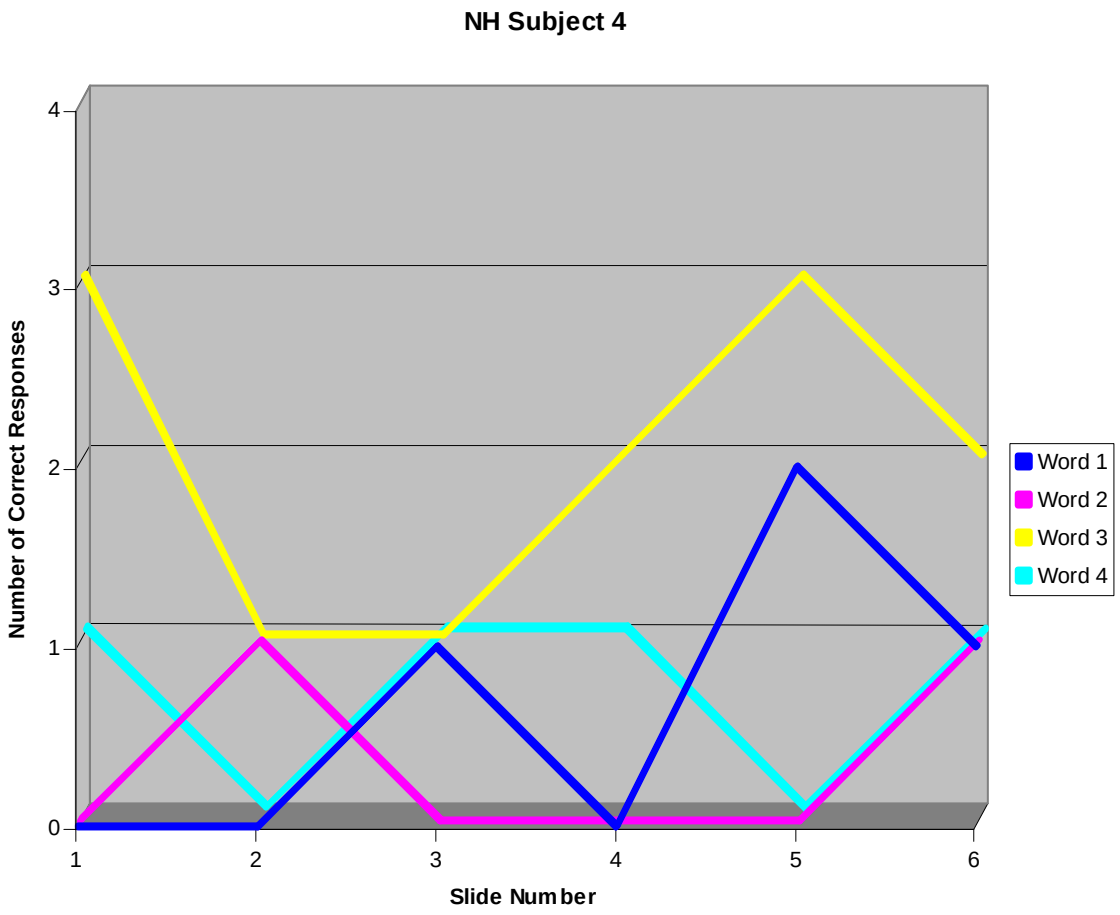
Graph 2


NH Subject 2
Number of Correct Responses
0
1
2
3
4
1
2
3
4
5
6
Slide Number
Word 1
Word 2
Word 3
Word 4

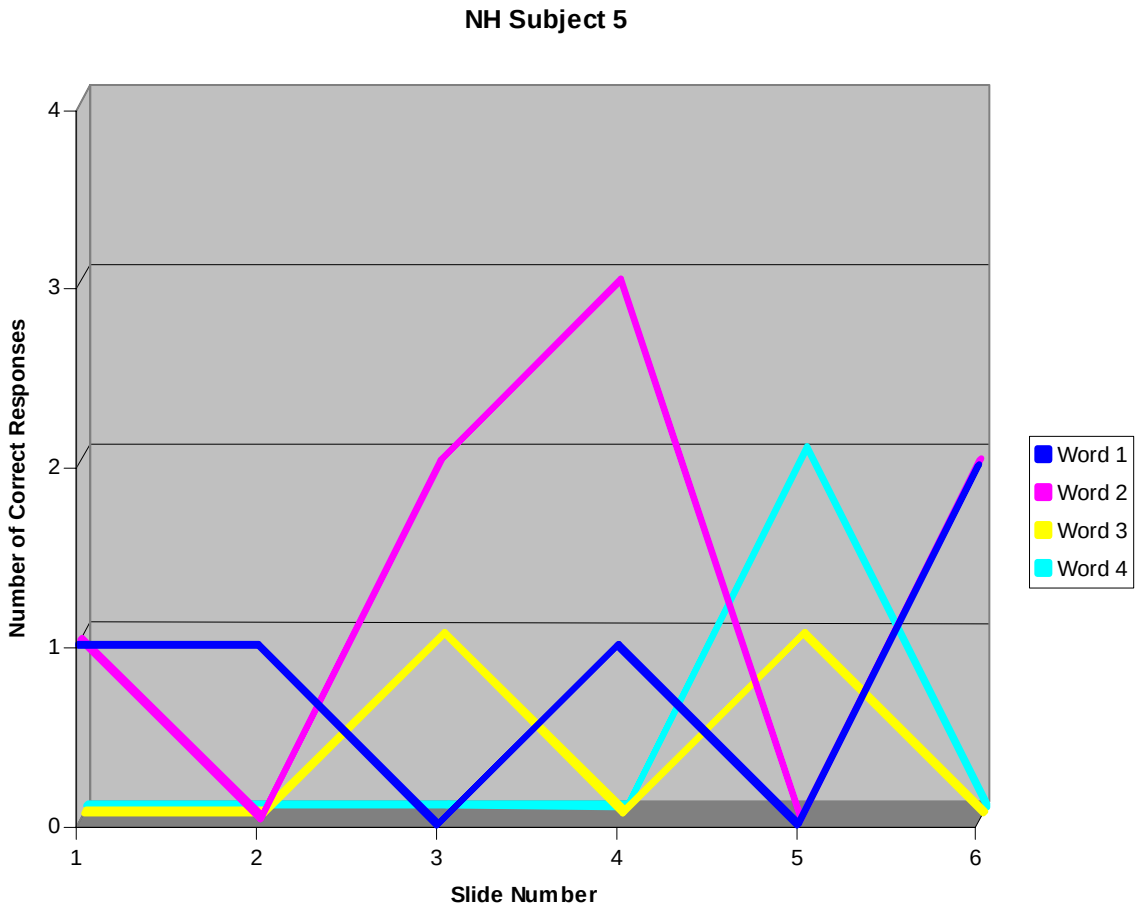
Graph 3


NH Subject 3
Number of Correct Responses
0
1
2
3
4
1
2
3
4
5
6
Slide Number
Word 1
Word 2
Word 3
Word 4

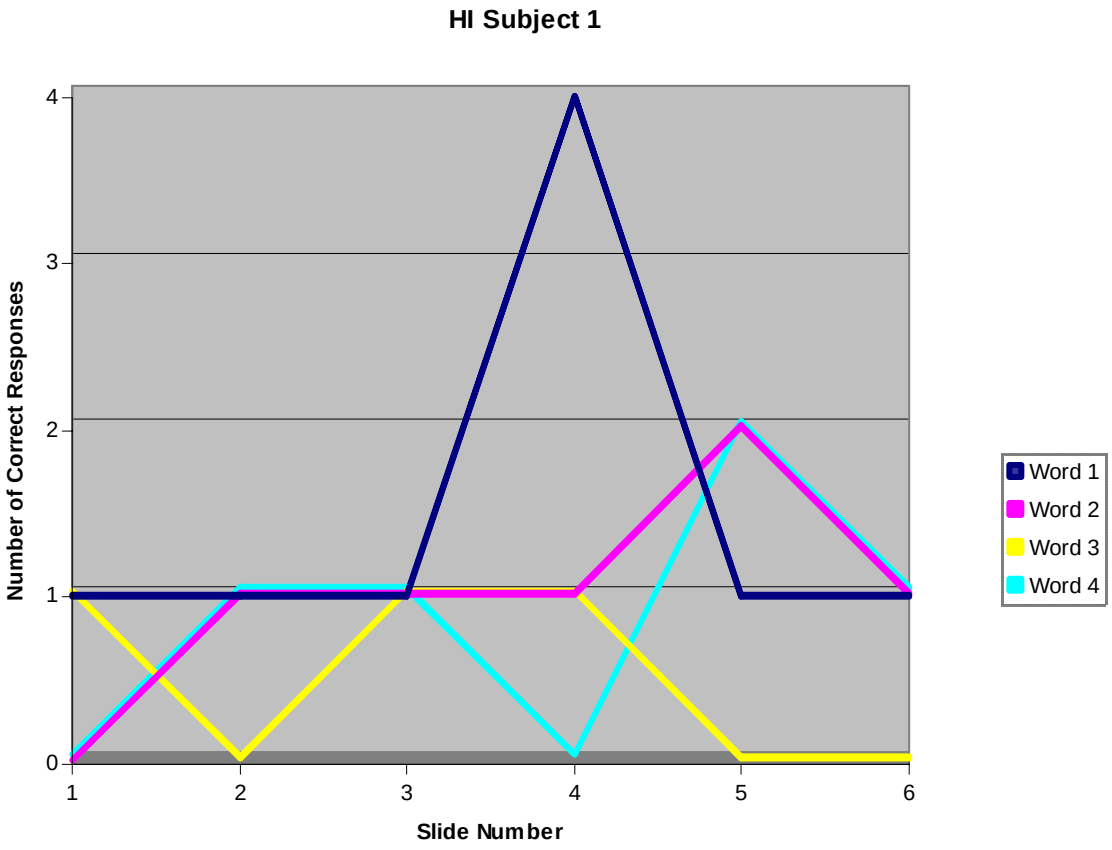
Graph 4


NH Subject 4
Number of Correct Responses
0
1
2
3
4
1
2
3
4
5
6
Slide Number
Word 1
Word 2
Word 3
Word 4

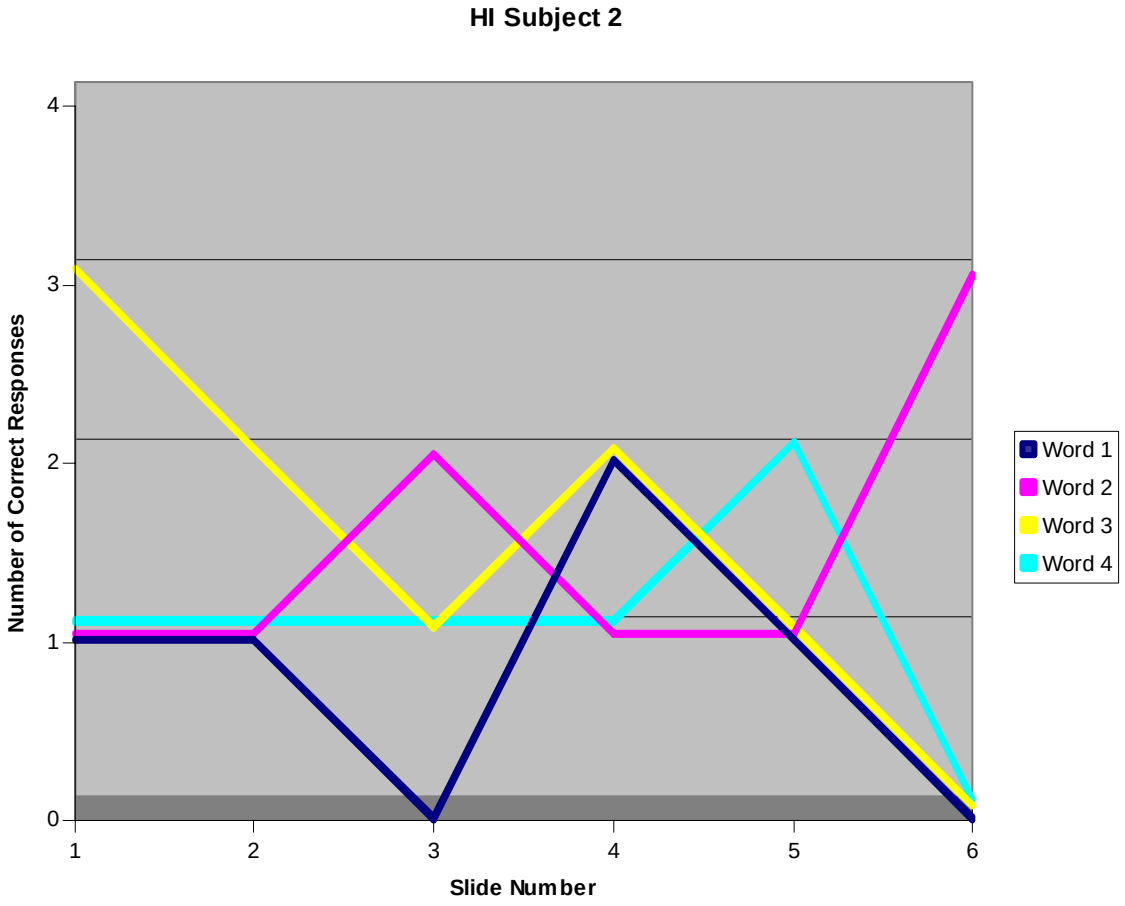
Graph 5


NH Subject 5
Number of Correct Responses
0
1
2
3
4
1
2
3
4
5
6
Slide Number
Word 1
Word 2
Word 3
Word 4

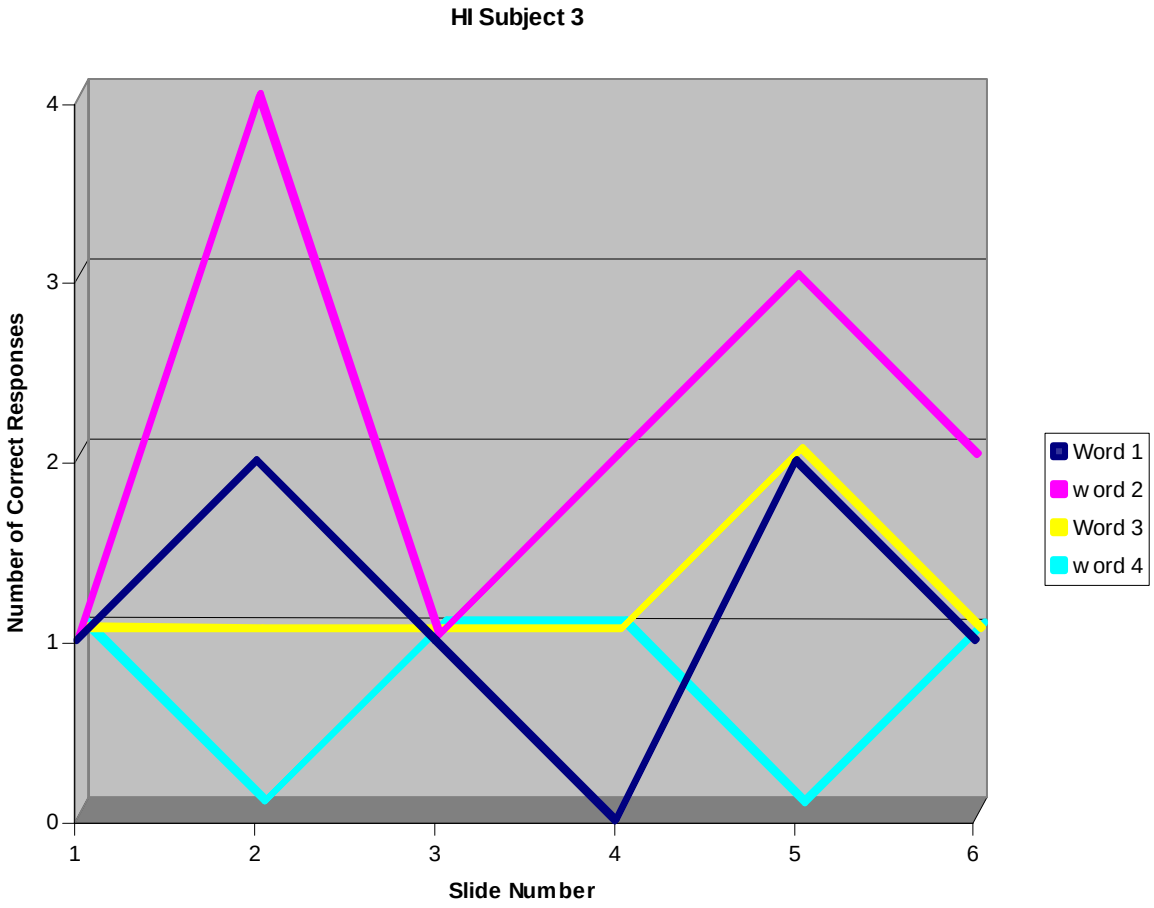
Graph 6


HI Subject 1
Number of Correct Responses
0
1
2
3
4
1
2
3
4
5
6
Slide Number
Word 1
Word 2
Word 3
Word 4

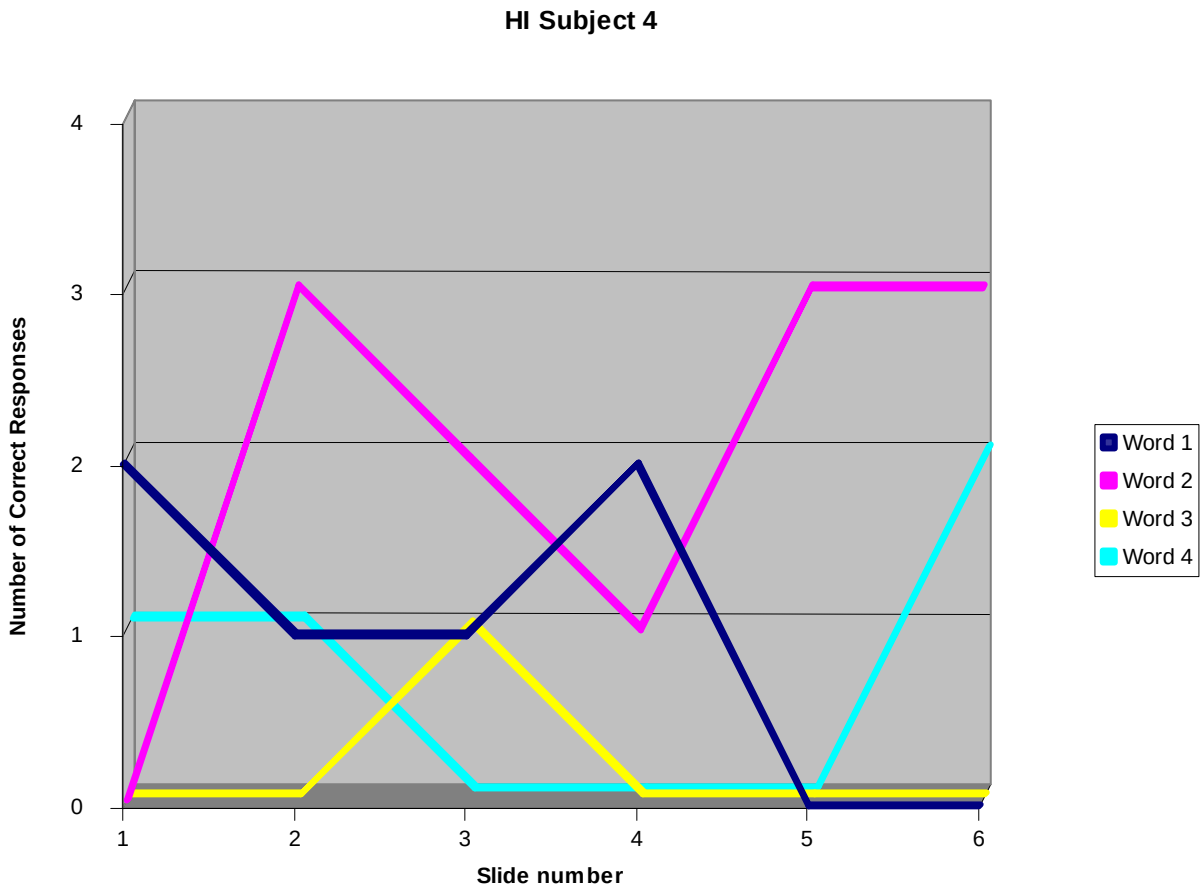
Graph 7


HI Subject 2
Number of Correct Responses
0
1
2
3
4
1
2
3
4
5
6
Slide Number
Word 1
Word 2
Word 3
Word 4

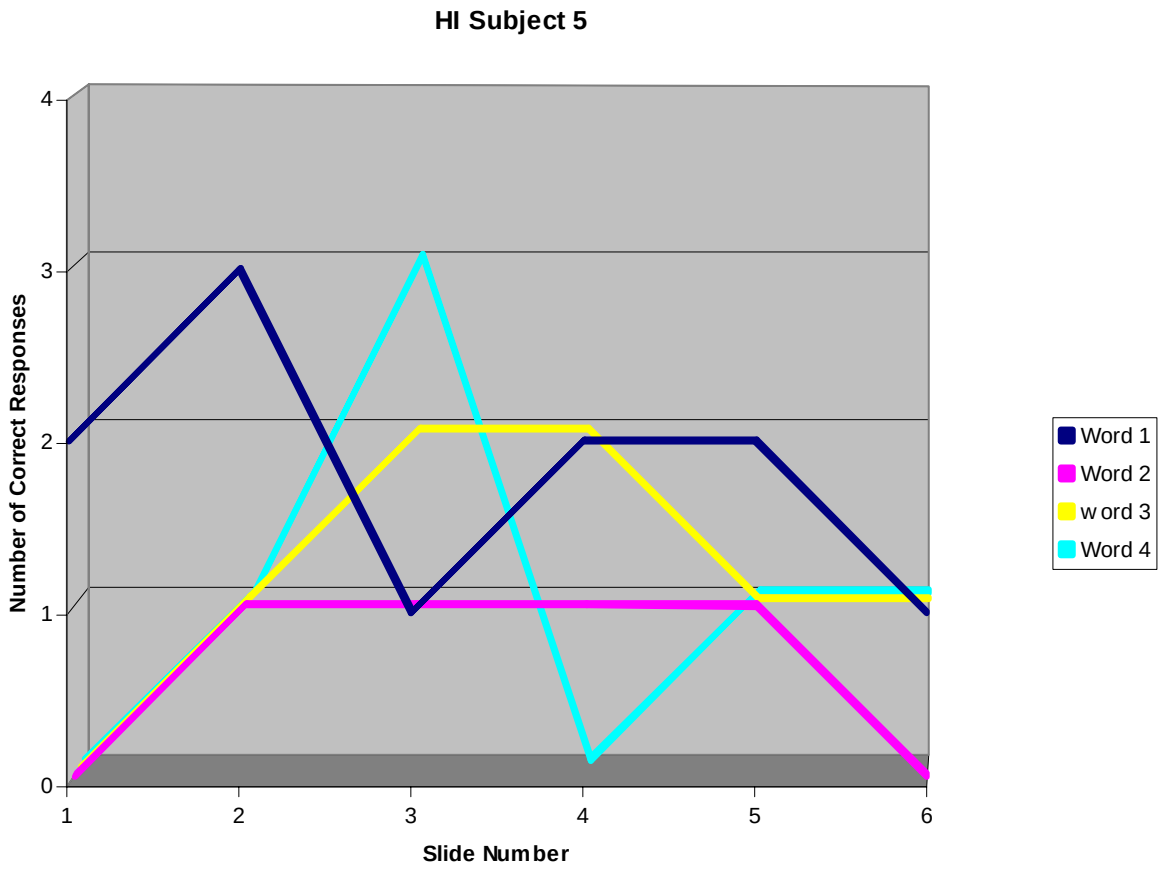
Graph 8


HI Subject 3
Number of Correct Responses
0
1
2
3
4
1
2
3
4
5
6
Slide Number
Word 1
word 2
Word 3
word 4

Graph 9


HI Subject 4
Number of Correct Responses
0
1
2
3
4
1
2
3
4
5
6
Slide number
Word 1
Word 2
Word 3
Word 4

Graph 10


HI Subject 5
Number of Correct Responses
0
1
2
3
4
1
2
3
4
5
6
Slide Number
Word 1
Word 2
word 3
Word 4

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