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**The Influence of Lexical Neighborhoods and Stimulus Sampling
Procedures on Children's Immediate Memory Span for Spoken Words:
A Report of Work in Progress¹**

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The Influence of Lexical Neighborhoods and Stimulus Sampling Procedures on Children's Immediate Memory Span for Spoken Words: A Report of Work in Progress

Abstract. Twenty-four normal-hearing children completed a memory span task requiring immediate recall of lists of spoken words. Memory span for lists of lexically “easy” words was compared to memory span for lists of lexically “hard” words, using items selected from the children’s Lexical Neighborhood Test (LNT; Kirk, Pisoni, & Osberger, 1995). In addition, two different “sampling” conditions were compared. Lists were created either by sampling repeatedly from a small closed set of words such that in each successive list, some words from previous lists were again heard, or by “non-repeated” sampling, such that on each list, every word was uniquely encountered. A main effect of sampling procedure was obtained. Overall, the children’s performance was better when the test items used were repeated within the set of lists in a given condition than when novel items were used for each test list. No significant main effect of the lexical discrimination manipulation was observed, although the means fell in the predicted direction; lists of lexically “easy” words were recalled somewhat better than lists composed of lexically “hard” words. No significant interaction was found. A revised version of this study is proposed.

Introduction

Recently, there has been renewed interest in the relationship between factors that influence the identification of spoken words and the mechanisms of phonological short-term memory. It has long been observed that short-term memory can hold only a remarkably small number of items (Miller, 1956) and that without the use of rehearsal or other maintenance processes, the information in short term storage is often lost within a matter of minutes (Atkinson & Shiffrin, 1971). The current paper is concerned with how young children’s representations of spoken words in long-term memory may interact with the short-term activation involved in performing an auditory short-term/working memory span task.

Users of a spoken language acquire a repertoire of words that they are able to recognize. Various authors have referred to these long-term memory representations as a language user’s “mental lexicon.” The structure of these mental representations has been argued to reflect certain key aspects of language experience. For example, some words in the language are encountered very often and are therefore robustly coded as high frequency lexical entries. Other words are less commonly encountered and thus may not be as firmly established in long-term memory. As a consequence, a low-frequency word may then be perceived less reliably than a high-frequency word. For example, the word “meek,” if heard out of context through noise, might be interpreted as “meat,” one of its *lexical neighbors*. Two words can be operationally defined as lexical neighbors of each other on a segmental level of analysis if a single phoneme can be substituted, subtracted or deleted to transform one word into the other (Landauer & Streeter, 1973; Luce, 1986). When a word has many such lexical neighbors, it is considered to be high in neighborhood density (Luce, Pisoni, & Goldinger, 1990). Word frequency and lexical neighborhood characteristics can combine to make some words particularly easy to identify and other words much harder to recognize. A word can operationally be defined as “hard” to identify if it is a low frequency item having many high frequency lexical neighbors: “competitive” activation of high-frequency neighbors hinders correct identification of the intended word. In contrast, a lexically “easy” word can be defined as being of high frequency and having few lexical neighbors, with its few existing neighbors being low in frequency. It has been shown that individuals

recognize lexically “easy” words more accurately than lexically “hard” words (Cluff & Luce, 1990; Kirk, Pisoni & Osberger, 1995; Luce, 1986; Luce, Pisoni, & Goldinger, 1990).

Word frequency and lexical neighborhood characteristics clearly depend critically on the language experience of the language user. An adult’s mental lexicon contains a large vocabulary of lexical items with very wide range in experienced frequency among the items. For an adult, with increased vocabulary size comes a greater likelihood of “densely populated” lexical neighborhoods. A young child’s lexicon, in contrast, is fairly limited. Vocabulary size is smaller and experienced frequencies are much lower. By virtue of a smaller vocabulary size, the number of neighbors that a child could potentially confuse a known word with is reduced (Charles-Luce & Luce, 1990; Charles-Luce & Luce, 1995).

The perceptual confusability of words within a child’s lexicon as predicted by word frequency and lexical neighborhood characteristics were investigated by Logan (1992) using children’s speech samples from the CHILDES database (MacWhinney & Snow, 1985). Logan found systematic relationships between the lexicons of preschool-age children and those of adults. In particular, neighborhood density increased as a function of age, suggesting that basic underlying principles of lexical organization might be similar for children and adults (see Charles-Luce & Luce (1990) however, for a discussion of key differences).

As an extension of Logan’s computational analyses, Kirk, Pisoni and Osberger (1995) developed the Lexical Neighborhood Test (LNT) to assess spoken word recognition in hearing-impaired children. One hundred monosyllabic words were chosen from the speech corpus previously analyzed by Logan. Multi-syllabic words, proper nouns, possessives, contractions, plurals and inflected forms of words were excluded from the LNT word lists. The words chosen consisted of 50 lexically “easy” words and 50 lexically “hard” words. Pediatric cochlear implant users, that is, hearing-impaired children that use a prosthetic device to receive partial auditory information via direct electrical stimulation of their auditory nerve, were tested on their ability to recognize lexically “easy” vs. lexically “hard” words. As predicted, Kirk, et al. found that these children displayed better open set word recognition scores for the LNT “easy” words than the LNT “hard” words. Whether or not these lexical influences continued to be demonstrated in auditory *memory* tasks, rather than just simple word identification tasks, was however, not tested at that time.

The original LNT word lists cannot be used to test for lexical influences in adults since these lists were specifically designed for preschool-age children. A database consisting of lexically “easy” vs. lexically “hard” words as defined as per a typical adult vocabulary was, however, recently constructed in our lab (see Torretta, 1995). In order to examine possible lexical influences on auditory memory span, Goh and Pisoni (1998) used this database to test adults’ immediate recall for lists of lexically “easy” vs. lexically “hard” words. They were also interested in whether the effects of prior exposure on immediate recall would differ in magnitude for “easy” vs. “hard” word lists. A sampling variable was therefore also manipulated. Some subjects were required to recall lists of words in which individual items were repeated from list to list, though never within a single list (“repeated sampling”). Another group of participants was required to recall lists in which a given word was never repeated either within or across lists (“non-repeated sampling”). After hearing the target list, the participants were required to write down the words in the correct serial order. Goh and Pisoni found that in the non-repeated sampling condition, memory span for lists of lexically “easy” words was significantly better than memory span for lists of lexically “hard” words. However, their results also showed that in the *repeated* sampling condition, neighborhood characteristics had little effect on memory span. The absence of a lexical effect in the repeated sampling condition was accounted for by proposing that the repeated use of the same lexical items from list to list only required repeated access to a small, and already activated subset of the adult’s mental

lexicon. Once the representations of the repeated words were successfully activated, it was suggested that on repeated exposure, neighborhood-competition effects had little influence on the probability of subsequent identification and interference with recall. In the non-repeated sampling conditions, however, there was uncertainty in identification not just due to the novelty of every word in each list, but in the “lexically hard” condition, also as result of each target word’s many lexical neighbors/competitors being activated during the identification process.

In the present study we attempted to replicate the results of Goh and Pisoni (1998) using the children’s LNT word lists already described. Like Goh and Pisoni, we manipulated the sampling variables (repeated vs. non-repeated) and the lexical characteristics of the test items used (“easy” vs. “hard”). Effects analogous to those obtained by Goh and Pisoni (1998) were predicted: i. e., evidence of a lexical effect (recall of “easy” words would be better than recall of “hard” words) in the non-repeated sampling condition, but not the repeated sampling condition. Obtaining this pattern of results would provide support for the hypothesis that lexical neighborhood characteristics influence the encoding of and memory for spoken words only when the items have not already been recently activated within the mental lexicon.

Method

Participants

Thirty normal-hearing children participated in the study. Six children were unable to complete the task. The data from twenty-four children were retained in the analysis. The children ranged in age from 53 months (4;5) to 89 months (7;5). In reporting the results below, the four- and five-year-old children between the ages of 53 to 70 months ($N=15$) are referred to as “the young group” while the remaining nine children, ranging in age from 76-89 months are referred to as “the older group.”

The wide range in ages represented in this sample arose for the following reason: Initially, we had planned to use this task with children for whom the LNT statistics were appropriate--that is, since the lexical characteristics of the LNT were designed to match the lexicons of three-to-five-year-old normally developing children, it would be most appropriate to see if children within this same age range would demonstrate a sensitivity to the neighborhood characteristics manipulation. However, after recruiting a number of young participants, it became clear that most of the four-year olds and some of the five-year olds simply could not complete the immediate recall task as required for inclusion in the data analysis. We then tried to recruit some older children to see how old the child had to be to complete the task as designed. We have since redesigned the procedure so that it can be run with young five-year-olds with reasonable levels of performance. This short report-in-progress, however, documents our early experimentation with the procedure. Since all variables were manipulated within subject, we can at least begin to look for possible effects in this sample, despite the wide age range.

Materials and Procedure

List Items. The stimulus materials were digitally recorded tokens taken from the LNT word lists (Kirk, Pisoni, & Osberger, 1995; Kirk, 1999). The LNT consists of one hundred monosyllabic words known to be familiar to children of age three years and up. This word list was specifically designed to contain words having very high vs. less high probability of accurate word recognition through the simultaneous manipulation of several variables. Half the words, the lexically “easy” words, were selected to be relatively more frequent in the child’s usage, to have relatively few lexical neighbors, and to have their lexical neighbors be high in frequency. The remaining words, the lexically “hard” words, were less

frequent (though still highly familiar) in children's speech and had many relatively high frequency lexical neighbors. Individually edited speech files were created by Kirk and her colleagues for a past study. Details of the recording process can be found in Kirk, Eisenberg, Martinez, and Hay-McCutcheon (1998). All LNT recordings were from a single young adult male talker. During the testing session, auditory materials were presented via a table-top loudspeaker (Advent Model AV280, 10 Watts amplifier output power, THD < 1%, frequency response 70 Hz-20 kHz) at approximately 70 dB SPL as determined via a hand-held sound level meter (Triplett Model 370) held at approximately the level of the child's head.

The lexical statistics for the words used in each of the four conditions in this study are provided in the Appendix. Statistics for each word were provided by authors of the LNT and are based on the corpus analyzed by Logan as previously mentioned. Forty-two words were required to create the word lists. Eight words from each of the LNT "easy" and "hard" lists were therefore eliminated (see note to Appendix). Six "easy" words and six "hard" words were selected from their respective LNT lists to be used in the "repeated" conditions. Both sets of six words were selected to roughly be representative of the larger list from which they were chosen, in terms of their lexical characteristics. The remaining thirty-six words from each list were used in the "non-repeated" conditions.

Lists. Presentation of the stimuli was controlled by a computer program specially created for this purpose, running on a PC computer. The child's responses were recorded on audio-tape using a omnidirectional microphone (Electro-Voice DO54 Dynamic Omni Directional Microphone) mounted on a table-top stand positioned approximately a foot away from the child's mouth, and a Sony audio cassette tape-recorder (Sony TC-D5M).

The lists were generated pseudo-randomly by the computer program. In the "non-repeated" condition, all words were used exactly once in a given test session. In the "repeated" sampling condition, the words in the six-word set were repeated from list to list, but not within any one list. A 500 ms delay was inserted between each list item. A computer-generated "bell-like" sound was played after the last item in each list as a signal for the child to begin recall.⁴

Each experimental condition contained eight word lists. The child heard two lists of three items apiece, two at length four, two at five, and two lists at length six. There were thirty-two lists total. A short break was instituted between each of the four conditions. The four conditions were counterbalanced across subjects (each of the twenty-four permutations of the four conditions was used exactly once).

Participants were tested at the Speech Research Laboratory at Indiana University by graduate and undergraduate research assistants. All children were tested individually in a quiet room. A practice trial was given to insure that the child understood what was being asked of them. The child was told to "repeat the list of words" back to the experimenter. The experimenter provided no explicit feedback regarding the accuracy of the child's responses. Verbal encouragement was given only to keep the child on task during the procedure. Because the procedure appeared to tax the attention span of most of the children we observed, coaxing was often required to get the child to finish the task. Each condition of the memory span task took approximately five minutes to complete, for a total length of approximately twenty to twenty-five minutes for all four conditions.

⁴ We had found that several pilot subjects began repeating the lists before presentation had finished. Although we are aware of possible "suffix" effects as reported in the literature on immediate recall (e.g., Conrad, 1960), this procedure was in place for all children and all conditions, and thus any resulting decrement in scores should be reflected in the means for every condition equally. Note that a "non-speech" suffix was used.

Scoring. All scoring procedures were identical to those used in the earlier study by Goh and Pisoni (1998). Goh and Pisoni used four different scoring criteria, of which we report only two—“total span” and “absolute span.” We used only these measures for analysis because the other scoring methods were far more conservative in awarding credit and yielded scores of zero for many participants. The Total Span score was obtained by counting how many words were recalled correctly in the correct list position regardless of whether the entire list was correct. The Absolute Span score was obtained by counting only those words that were recalled in the context of a list that was perfectly recalled. For both Total and Absolute Span scoring methods, the child’s set of responses was aligned such that the cardinal position of the response had to match that in the presented list to be marked correct. For example, if the target list was “toe, dry, game” and the child said, “dry, game,” no points were awarded for either Total or Absolute Span. This scoring procedure, which requires correct recall of both item and order information, was adopted to match the paper-and-pencil scoring methods used in Goh and Pisoni.

WISC Digit Span. In order to obtain a widely used and accepted measure of memory span against which to compare the word span results, all of the children also completed the WISC Digit Span Supplementary Verbal Sub-test of the Wechsler Intelligence Scale for Children, Third Edition (WISC-III; Wechsler, 1991). A recorded version of this test that was created for another study (Kirk, 1999) was used. This memory span task requires the child to repeat back a list of digits as spoken by a recorded female talker at a rate of approximately one digit per second (WISC-III Manual; Wechsler, 1991). In the “digits-forward” section of the task, the child is required to simply repeat back the list as heard. In the “digits-backwards” section of the task, the child is told to “say the list backward.” An example of reversing a list length of two items is provided and a practice trial is given for the backwards task. In both parts of the WISC task, the lists begin with two items, and are subsequently increased in length upon successful repetition until a child gets two lists incorrect at a given length, at which point testing stops. Points are awarded for each list correctly repeated with no partial credit. The WISC-III testing manual provides two lists for use at each list length, with the possible list length ranging from two to nine items in the forward condition, and from two to eight items in the backwards condition. Digits are not repeated consecutively within any list and each list is unique.

Results and Discussion

An alpha level of .05 was adopted for all statistical tests reported below. The means for Total Span scores in each of the four conditions are shown in Figure 1. The average spans for the “repeated” conditions are shown in the two bars to the right, while the average spans for the “non-repeated” sampling conditions are shown on the left. Clear bars indicate the means for the “easy” word list conditions and the hatched bars the means for the “hard” word list conditions. As can be seen from the figure, performance was better in the “repeated” sampling conditions than in the “non-repeated” sampling conditions. Contrary to expectation, however, little to no advantage was observed for the “easy” word list conditions over the “hard” word list conditions. A 2 x 2 repeated measures ANOVA on the Total Span scores showed a significant main effect of “repeated” vs. “non-repeated” sampling, $F(1, 23) = 16, p = .001, MS_e = 9.53$. No significant main effect was obtained for the “easy” vs. “hard” manipulation and there was no statistical evidence of an interaction (all $F_s < 1$). Analogous results were obtained using the Absolute Span scores, once again showing a significant main effect of sampling, $F(1, 23) = 14.24, p < .01, MS_e = 14.34$, and no evidence of either a main effect of lexical neighborhood or an interaction.

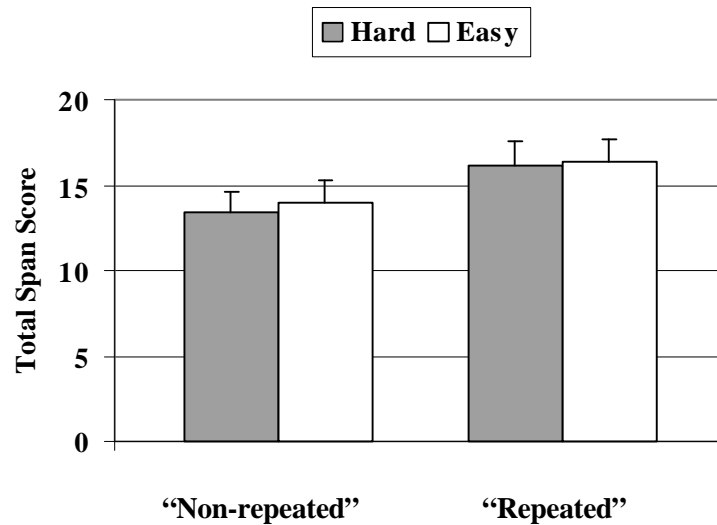


Figure 1. Mean spans (+SE) for “Non-Repeated” [left] vs. “Repeated” [right] conditions. Hatched bars indicate mean span in “Hard” word conditions, clear bars indicate mean span for “Easy Word” conditions.

The data in Figure 2 indicate that for this younger subgroup of children, repeated sampling clearly resulted in significantly higher Total Span scores ($F(1, 14) = 10.67, p < .01, MS_e = 11.83$), and that lexically “easy” word lists tended to be better recalled than lexically “hard” word lists $F(1, 14) = 3.78, p = .07, MS_e = 7.41$, although this difference did not reach statistical significance. Note also that while the overall “easy” vs. “hard” effect fell in the predicted direction, this difference was slightly larger in the “repeated” sampling conditions as opposed to the “non-repeated” sampling conditions, contradicting our prediction that the lexical manipulation would have an effect only in the “non-repeated” conditions. The interaction between sampling and lexical neighborhood was not significant, $p = .33$. Analogous analyses on the Absolute Span scores gave a very similar pattern of results: a significant main effect of sampling, $F(1, 14) = 5.20, p < .05, MS_e = 16.61$, weak evidence of a main effect of lexical neighborhood, $F(1, 14) = 2.90, p = .11, MS_e = 7.46$, and no interaction between the two variables.

At the time of this writing, the data set from the fifteen four and five year olds is not completely counterbalanced. Additional subjects need to be recruited to complete this data set. The remaining nine children (age 6 and 7 years), demonstrated the sampling effect, but showed little influence of the “easy” vs. “hard” word manipulation in the “non-repeated” condition (like the younger children). These older children also showed a non-significant difference in the “repeated” condition in the direction opposite to that predicted, thus contributing to failure to find a main effect of neighborhood in the larger group of twenty-four children.

The correlations between children’s WISC verbal digit spans and their word span scores in each of the four experimental conditions (scored as “total span”) are shown below in Table I. As expected, these two sets of measures were, in general, strongly positively correlated. We had, however, expected that the

forward digit span measure would correlate more highly with the repeated-sampling word-span conditions than the non-repeated word span conditions, since digit span involves repeated sampling from a small set of possible items. As can be seen in Table I, the data did not provide support for this conjecture.

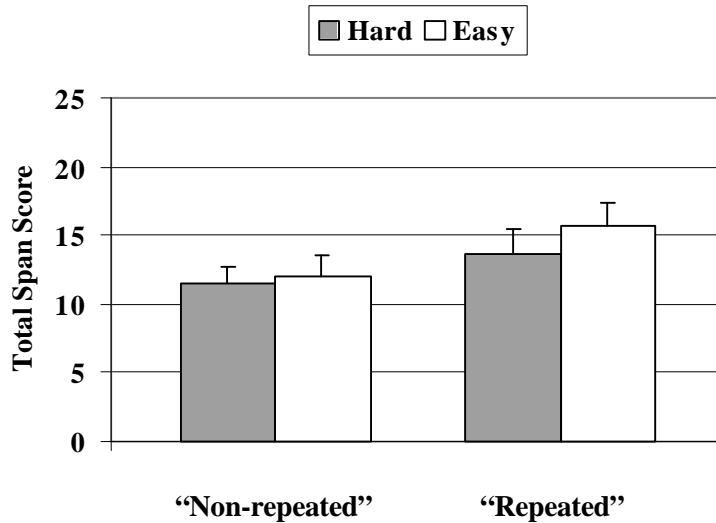


Figure 2. Mean spans (+SE) for only the four- and five-year old children (N=15) in the “Non-Repeated” [left] vs. “Repeated” [right] conditions. Hatched bars indicate mean span in “Hard” word conditions, clear bars indicate mean span for “Easy Word” conditions.

Although we still have to collect additional data, several trends are already clear. Both groups of children are clearly sensitive to the sampling manipulation, thus showing that when spoken words have already been identified and activated from long-term memory, subsequent recall using these same words is better than when novel words must be accessed for every list. The lexical neighborhood manipulation, however, is difficult to interpret due to methodological problems that we are currently in the process of rectifying. The memory task needs to be made easier, and the lexical statistics must be appropriate to the age group tested. It would also probably be preferable to rotate the six words chosen for the repeated conditions across the items in the “easy” and “hard” word lists for different subjects rather than using the same set of six words as we did in this version of the experiment. (A fixed set of eight words was also used for all subjects in Goh and Pisoni [1998]). This manipulation might help to insure that the sampling effect and any neighborhood effects that might be obtained are not due specifically to the word set used but to the independent variables being manipulated.

	WISC Forward Digit Span	WISC Backward Digit Span
Non-repeated Hard	.71**	.31
Non-repeated Easy	.41	.53*
Repeated Hard	.42*	.54**
Repeated Easy	.60**	.29

*p < .05

** $p < .01$

Table I. Correlations between WISC digit span measures and LNT word span conditions. Age in months, although not a strong co-variate, has been statistically partialled out.

It would also be advantageous to be able to separate out the independent effects of word frequency, neighborhood density, and neighborhood frequency in contributing to any lexical neighborhood effects found. To do this, new word lists specifically designed to test these factors will need to be constructed. A revised study is underway to address some of these issues.

In summary, the present study replicated the main effect of the stimulus sampling procedure as reported by Goh and Pisoni (1998) but failed to obtain evidence in young children for the interesting lexical interaction reported in that paper--namely, that lexical neighborhood effects influence the encoding of and memory for spoken words only when the items have not already been recently (and repeatedly) activated within the mental lexicon.

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Appendix

Eliminated LNT words: (Easy: down, old, orange, six, three, want, watch. Hard: cut, cut, ear, mine, nine, ten, zoo.) Rationale: not clearly a monosyllabic word (“orange”), number names since digit span was used as a separate task (“six,” “three,” “nine,” “ten”), extreme on the frequency distribution (“want,” “down,” “watch,” “put”), incomplete statistics available (“zoo”), function word with low intelligibility (“mine”), appears twice on LNT (“cut,” “cut”), began with a vowel (“old,” “ear”), potentially confusing (“wrong”).

Lexical Statistics for Words Used in the Easy Repeated Condition

	Orthography	Pronunciation	Word Frequency	Mean Neighborhood Density	Mean Neighborhood Frequency
1	live	lIv	4	3	4
2	jump	J^mp	5	1	2
3	cold	kold	5	3	16.33
4	need	nId	16	2	3
5	boy	bO	16	4	8
6	truck	tr^k	4	1	2
		MEAN	8.33	2.33	5.89
		SD	5.96	1.21	5.58

Lexical Statistics for Words Used in the Hard Repeated Condition

	Orthography	Pronunciation	Word Frequency	Mean Neighborhood Density	Mean Neighborhood Frequency
1	fat	f@t	1	8	14
2	cake	kek	3	8	6
3	toe	to	2	11	52.36
4	use	yuz	2	4	55
5	dry	drY	1	4	4
6	game	gem	1	4	2
		MEAN	1.67	6.50	22.23
		SD	0.82	2.95	24.72

Lexical Statistics for Words Used in the Easy Non-Repeated Condition

	Orthography	Pronunciation	Word Frequency	Mean Neighborhood Density	Mean Neighborhood Frequency
1	farm	farm	15	1	2
2	house	hWs	14	2	24
3	white	hwYt	11	2	41.5
4	gray	gre	11	1	2
5	brown	brWn	11	1	1
6	drive	drYv	10	2	2
7	green	grin	10	0	0
8	break	brek	9	1	9
9	snake	snek	9	1	1
10	food	fud	9	0	0
11	push	pUS	8	2	30
12	count	kWnt	8	2	15
13	friend	frEnd	8	1	3
14	girl	gRI	8	1	1
15	good	gUd	12	4	3
16	more	mor	7	3	21
17	stop	stap	7	3	3
18	school	skul	7	1	8
19	give	gIv	7	1	4
20	cow	kW	6	4	34
21	home	hom	6	4	4
22	sit	sIt	5	4	52
23	hold	hold	5	4	12
24	hard	hard	8	2	1
25	bird	bRd	5	3	2.67
26	fish	fIS	8	0	0
27	mouth	mWT	5	0	0
28	foot	fUt	4	3	17
29	catch	k@C	4	3	16
30	hurt	hRt	5	3	3
31	swim	swIm	4	3	2
32	dance	d@ns	4	2	9.5
33	time	tYm	10	4	10
34	juice	Jus	4	1	1
35	stand	st@nd	4	0	0
36	pig	pIg	14	4	8
		MEAN	7.83	2.03	9.52
		SD	3.08	1.36	12.70

Lexical Statistics for Words Used in the Hard Non-Repeated Condition

	Orthography	Pronunciation	Word Frequency	Mean Neighborhood Density	Mean Neighborhood Frequency
1	pie	pY	4	11	60
2	wet	wEt	4	8	12.5
3	sing	sIG	4	8	3
4	hand	h@nd	4	5	40
5	read	rid	4	5	7
6	hi	hY	3	16	56
7	tea	ti	3	14	48
8	hot	hat	3	11	14
9	call	kal	3	8	11
10	fun	f^n	3	6	18
11	ball	bal	3	6	10
12	book	bUk	3	6	7
13	work	wRk	3	5	1
14	cut	k^t	3	4	12
15	dad	d@d	2	8	17
16	bed	bEd	2	7	5
17	cook	kUk	2	6	6
18	pink	pIGk	2	5	3
19	grow	gro	2	4	18
20	lost	last	2	4	3
21	fight	fYt	1	10	4
22	goat	got	1	8	31
23	toy	tO	1	7	43
24	gum	g^m	1	7	18
25	bone	bon	1	7	11
26	sun	s^n	1	6	24.83
27	thumb	T^m	1	6	21
28	seat	sit	1	6	20.17
29	run	r^n	1	6	17
30	cap	k@p	1	6	11
31	kick	kIk	1	6	2
32	meat	mit	1	5	14
33	bag	b@g	1	5	10
34	ride	rYd	1	5	8
35	song	saG	1	5	4.4
36	bath	b@t	1	5	4
MEAN			2.08	6.86	16.53
SD			1.13	2.66	15.30

