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Lexical Neighborhood Effects in 17-Month-Old Word Learning

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How might infant's existing vocabulary affect their ability to learn new words? Specifically, how does the density and token frequency of lexical neighbors in the speech surrounding a child affect that child's ability to learn new word-to-world mappings? The current paper presents a series of studies that demonstrate strong effects of lexical neighborhoods on 17-month-old infant's abilities to learn new words. These effects were created with only a small amount of exposure with little or no opportunity for semantic factors to overlap. Thus, it appears that simply hearing a word can make it easier or harder to learn depending on the number and frequency of items surrounding that word in the lexicon.

Lexical neighbors are words that sound similar to a target item. Empirically, they are often defined as words that differ by a single phoneme from a particular item (Vitevitch & Luce, 1998). Thus, for example some lexical neighbors of the word *cat* would be: *at*, *scat*, *pat*, *cut*, and *cap*. In addition, some lexical neighborhoods are denser than others. For example, the -*at* rhyme appears in words such as *cat*, *hat*, *mat*, *sat*, *bat*, *rat*, *fat*, *pat*, and *vat*, while the -*up* rhyme appears only in *cup* and *pup*. Furthermore, all other things being equal, adults are slower at recognizing words from dense lexical neighborhoods than sparse one (Luce & Pisoni, 1998; Pisoni et al., 1985; Vitevitch & Luce, 1998).

Explanations for this effect tend to focus on some form of phonological/lexical competition. That is, the more similar words surrounding a target in the lexicon, the more possible candidates competing for attention, and the harder it becomes for the speech recognizer to establish the actual input (Marslen-Wilson, 1989; McClelland & Elman, 1986; Norris, 1984). Although these accounts differ widely on the form that such competition might take, the question remains as to how and when such lexical neighborhoods develop and whether or not these neighborhoods exhibit the same kind of competitive effects in infants as those seen in adults. Furthermore, how might such neighborhoods affect infants' abilities to learn new words? What do such effects imply for 17-

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month-old infants, who are at the cusp of the word-learning explosion? For example, a child who knows the word *bat* could learn the word *hat* more quickly because familiarity with the *–at* sound structure makes it easier to focus on the mapping between word and object. In contrast, the mere existence of the word *bat* in that child's vocabulary might make that child unwilling to assign a new word object pairing to a phonological item so close in pronunciation.

The preliminary evidence for lexical neighborhood effects is unambiguous, if somewhat complex. That is, there is a host of studies that seem to indicate that infants possess rather sophisticated phonological specificity for speech representations (Eimas et al., 1971; Jusczyk & Aslin,1995). For example, Jusczyk and Aslin (1995) were able to show that 7.5-month-old infants familiarized with the word *cup* would not false alarm to words such as *cut*. Similarly, Swingley, Pinto, & Fernald, (1999) find that infants are slower to recognize mispronunciations of familiar words in a preferential looking task – also supporting the idea that infant have detailed phonological representations for words.

However, when it comes time to teach infants the meaning for similar sounding words, infants (even 24 months of age) seem to be considerably impaired (Barton, 1978; Gerken, Murphy & Aslin, 1995; Shvachkin, 1973; Stager & Werker, 1997). A particularly telling example of this can be found in the work of Stager and Werker (1997). They found that 14-month-old infants would dis-habituate when a speech signal changed from *bih* to *dih*, but only if the visual display accompanying these stimuli was a neutral checkerboard pattern. In contrast, when they attempted to pair two novel objects with the two differingspeech signals, the infants did not show evidence of learning the appropriate mappings.

Thus, it appears that while infants are sensitive to tiny differences in pronunciation, they require larger phonological differences in establishing independent lexical representations. Under this hypothesis then, infants are cautious word learners who require a great deal of evidence before they are willing to assign new lexical status to an item. Not only is such a strategy adaptive, as infants must recognize many different realizations of the same word in different contexts, but this account is also consistent with other findings in early infant word learning that suggest infants are extremely conservative in their willingness to attach word and meaning (see for example Hollich, Hirsh-Pasek, and Golinkoff, 2000).

However, infants must ultimately learn words that sound similar. From Dr. Seuss to alliteration, the structure of language is such that some overlap is inevitable. Instead of having to learn two words that sound similar, infants often find themselves having to learn up to six similar sounding words, on average, and in some cases as many as thirty-four (Charles-Luce & Luce (1990, 1995). This raises the question of how infants' internal phonological representations for existing words could affect their ability to learn similar sounding words. More specifically, the goal of the current series of studies was to directly examine the effects of lexical density and token frequency in children's acquisition of two new word-to-world mappings. However because it was known that learning two similar words is difficult, we decided to teach infants two dissimilar words whose neighborhoods had different densities. Furthermore, because infants know only a small number of words, because there is great variability in what those words might be, because frequency is also problematic, and because conceptual factors could also play a role, we decided to use nonsense words from low density, low frequency (in English) neighborhoods.

1. Experiment 1: Density Effects

Experiment 1 tested the effects of prior familiarization with lexical neighbors on 17-month-old abilities to learn new words. This experiment used use the headturn preference procedure for familiarization and the split-screen preferential looking paradigm for training and test. The headturn preference procedure was used to familiarize infants with a dense and a sparse neighborhood. After familiarization, the split-screen procedure was used to test infants on their ability to learn a referent for the target words of these neighborhoods. It was expected that the infants should learn the target word from the sparse neighborhood better than the target from the dense neighborhood.

The participants were 20 17-month-olds from monolingual American-English-speaking homes (mean age: 17.07 months, range: 16.75 months to 17.48 months). Eight additional infants were tested, but their data were not included because of excessive fussiness or crying.

1.1. Stimuli

Four lists of 12 CVC words (see Table 1) were created to constitute the familiarization portion of the study, although individual children would hear only two of these lists. Two of the lists, the high-density lists, consisted of 12 phonetic neighbors of the target words: *tirb* and *pawch*. Four of these neighbors differed from the target word in their initial consonant, four in the vowel, and four in the final consonant. The other two lists, the low-density lists, consisted of three of the same neighbors (one each differing in the initial consonant, vowel, or final consonant) from the high-density list and nine filler items that were unrelated to the neighbors.

Six different orders of the lists were recorded, thus providing for a variety of tokens and making the lists more interesting. While the orders were random, the low-density lists had the constraint that one of the neighbors had to be present within the first four words. Furthermore, across the six low-density lists, the neighbors present in the first four words were balanced so that there were two that began with the same initial consonant, two with the same vowel, and two with the final consonant.

Table 1. The neighborhoods used in the experiments.

High Density		Low Density	
Tirb	Pawch	Tirb	Pawch
tirng	pawv	hoyv	tav
tirch	pawth	deeve	weem
tirth	pawng	tirng	pawng
tirsh	pawsh	koys	fahsh
lirb	thawch	laze	cheth
thirb	rawch	nith	soyng
mirb	nawch	shirb	nawch
shirb	sawch	rauch	thich
tahb	paych	shawg	muhl
tuhb	pech	tahb	pech
tib	poych	zope	bauch
toyb	puch	girj	koeth

** Note. All words were presented in random order.

All of the speech samples were recorded with a Shure microphone in a sound-shielded booth by a female native speaker of American-English. Stimuli were digitized on a Computerized Speech Lab (CSL) Model 4300B produced by Kay Elemetrics, at a 20kHz sampling rate via the 16 bit analog-to-digital converter. Digitized versions of the samples (in AIFF format) were transferred to a Macintosh G4 computer for playback during the familiarization portion of the experiment. The average loudness level of the samples, measured with a Quest (Model 215) sound level meter, was 70 ± 2 dB(C) SPL.

For the audio portion of the second half of the study, including the training and test phases, 36 different tokens of the target words were recorded, using the setup described above. For the video portion, two novel objects were designed, and rendered, using Macromedia's Extreme 3D program, a tool for three dimensional modeling and animation. These pictures were then rendered into the splitscreen format using Digital Origin's EditDV software program and the picture-in-picture filter of that program. When presented, the individual pictures of the splitscreen stimuli measured approximately eighteen inches in width by one foot in height. The distance between the pictures was nineteen inches from center to center.

The audio and video were edited together and arranged into training and test blocks in the form described in Table 2. On training trials, only one of the objects was shown, while on test trials both were shown side by side. Each trial was six seconds in length, and repeated the target word at 1, 3, and 5 seconds from the beginning of the trial. On the fifth second after the onset of a trial, the correct object would briefly bob up and down. This motion was included to reinforce infants as to the target of each trial and to increase the likelihood that they would look toward the target during the first five seconds. The data from the last second was excluded from analysis. Likewise, data from the first second (before the target word was given) was also excluded from the analysis. In addition to the training and test trials, two known word trials were added to the beginning of the experiment in order to familiarize infants with the nature of the task and to provide a baseline measure for infant performance in this task. It should be noted that in all experiments, infants looked longer at the targeted known words in these trials. A two second intertribal interval was between all trials. It consisted of a smiling baby inside a centrally placed circle. No audio was played during this time.

Table 2. Splitscreen trials.

Visual Display	Sound Track
Familiarization	
Book & Keys	"Book" (x 3)
Book & Keys	"Keys" (x 3)
Training	
Tirb	“Tirb” (x 3)
Pawch	“Pawch” (x 3)
Test	
Tirb & Pawch	“Tirb” (x 3)
Tirb & Pawch	“Pawch” (x 3)
Tirb & Pawch	“Pawch” (x 3)
Tirb & Pawch	“Tirb” (x3)

** Note. Each set of trials was counterbalanced. The test and training trials were repeated twice.

1.2. Design.

Using the headturn preference procedure, infants were familiarized with two types of neighborhood lists: the high density and the low density. A different random ordering of the lists was used in each block. Infants heard each type of list six times. We expected that this high number of repetitions would be sufficient to give infants the opportunity to encode the sound patterns of the individual neighbors.

After familiarization, the infants were tested in the splitscreen procedure, and the known word trials and three blocks of training and test trials were played. All children across all experiments heard and saw the same conditions during this portion of the experiment. The only difference in these studies was in the two kinds of familiarization played to the infants (aka whether infants heard *tirb* as high and *pawch* as low or vice versa).

1.3. Apparatus

In the familiarization phase, the Macintosh G4 controlled the presentation of the samples. The audio output for the experiment was generated from the digitized waveforms of the samples. The output was fed through a Harmon Kardon audio amplifier (HK-3250) to one of two Cambridge Soundworks (Ensemble II) loudspeakers mounted on the opposite walls of a three-sided enclosure (constructed out of 4 x 6 pegboard panels). On the center panel of the enclosure, directly facing the infant, was a green light mounted at eye level that could be flashed to attract the infants attention. A red light, which also could be flashed, was mounted above each of the hidden loudspeakers on the two side panels. An experimenter, seated behind the center panel, observed the infant. This experimenter initiated each trial by operating a response box linked to the G4 computer. Computer software controlled the selection and randomization of the stimuli. A white curtain suspended around the top of the booth shielded the infants view of the rest of the room.

In the word learning portion of the experiment, a Sony TRV-7000 Digital8 Camcorder was used to play the video stimuli. This video was presented on a 56 inch Sony KLW-9000 LCD Presentation Display. A second Sony TRV-7000 Digital8 Camcorder mounted above the display recorded infant looking, for subsequent frame by frame coding. A large plywood partition, painted white, covered all but the screen of the display and the lens of the camcorder. The partition was present in order to minimize looking to extraneous objects such as the displays volume knobs, the camera microphone, etc.

1.4. Procedure.

For the familiarization portion of the experiment, each infant sat on a caregiver's lap in a chair in the center of the three-sided enclosure. A trial began with the flashing of the green light on the center panel. When the infant fixated on the green light, it was extinguished, and a red light on one of the side panels began to flash. When the infant made a head turn of at least 30 degrees towards the flashing light, the experimenter initiated the speech sample from the loudspeaker under that light. In order to ensure that each infant heard the same stimuli, the list on each trial would play through to completion regardless of where the infants subsequently looked. Following the completion of the list, the green center light would begin to flash, signaling the beginning of a new trial. Both the experimenter and caregiver wore Peltor Aviation 7050 sound-insulated headphones that were playing masking music to prevent him or her from hearing the stimulus materials throughout the duration of the experiment.

In the word learning section, infants sat approximately 45 inches from the presentation display, while the video was played in its entirety. However, if infants turned away during a trial, or at the end of a trial, the experimenter would pause the video during the intertrial interval in order to ensure that the infant was looking at the screen for the beginning of each trial. The caregiver wore a blindfold in order to prevent him or her from seeing the target objects throughout the duration of the experiment.

1.5. Coding

All coding was conducted off-line. Digital Origin's EditDV program was used to control the videos of the participants responding. This program allowed coders, blind to the condition being run, to step through these videos, frame by frame, and to mark the beginnings and ends of each left and right look, for all trials. These marks were then exported to a spreadsheet for analysis of the mean looking times to the target and non-target objects. Because of the frame by frame nature of this process, this method was extremely accurate (to within one thirtieth of a second), and inter-rater reliability was kept above .98 percent.

1.6. Results and Discussion

The mean looking times are presented in Table 3. They indicate that infants looked longer at the target over the non-target only in the low-density condition, t (19) = 3.12, p = .002.

Table 3. Mean looking times.

	Target		Non-Target
Experiment 1 (6x)			
High Density	1.44 (.10)		1.64 (.12)
Low Density	1.87 (.13)	*	1.22 (.13)
Control Study	1.54 (.08)		1.48 (.08)
Experiment 2a (1x)			
High Density	1.76 (.11)	*	1.35 (.10)
Low Density	1.55 (.08)		1.55 (.13)
Experiment 2b (1x, Token)			
High Density	1.52 (.11)	*	1.24 (.10)
Low Density	1.37 (.10)		1.35 (.12)

* $p < .05$

It seems that infants did learn the word from the sparse neighborhood better than the word from the dense neighborhood. In fact, it was the only word they reliably learned. These results are in line with those from adult studies showing that targets from dense lexical neighborhoods tend to be recognized more slowly than those from sparse neighborhoods. They also extend such findings by suggesting that infants can construct similarity-based, competitive networks with as little as two minutes' exposure. It would appear that such competitive effects arise even in the process of acquiring new words and even in the absence of any semantic representations for the competitors. Most importantly, however, it would appear that although acoustic representations can be created and maintained in the absence of semantics, they nonetheless have a strong effect on semantic acquisition.

2. Experiment 2 and 3: Probabilistic Effects

Interestingly however, infants were even better in the low-density condition of experiment 1 than in a control study, which used the same training and test but which familiarized infants six times through two lists of filler items (see Table 3), t (19) = 0.48, *p* = n.s. Thus, it appears that having heard some neighbors can be beneficial. This raises the question of why infants learned words in the low-density condition better than having heard no neighborhood at all.

One possible answer appears to be that infants are sensitive to phonotactic probabilities. That is, for example, in the previous study, in the low density condition (for *tirb*) infants had been exposed to the *–irb* sound pattern, the *tir-* pattern, and the *t_b* pattern six times each. Under this hypothesis, their familiarity with these co-occurrences of phonemes helped infants recognize and process the target word *tirb* faster. Notice that this can't be all that was occurring because infants had also heard, in the high-density condition, the *–awch* pattern, the *paw-* pattern and the *p_ch* pattern twenty-four times each. Thus, while there is a competitive, inhibitory effect of density, there may also be an opposite, facilitation effect for phonotactic probabilities.

This suggests an interesting manipulation. What would happen if the infants heard the lists only one time through? Then our new high-density (with four times through each of the phonotactic pairings) would be most similar to old low density (with six times through the phonotactic pairings). In such a case, if the phonotactic hypothesis is true, we would expect that our results would reverse – now the new high density would be better than the new low-density. Furthermore, if the phonotactic hypothesis is true, then we would also expect that the same results would be seen if infants were familiarized with the target words instead of the neighbors (12 times in the "high density" case and 3 times in the "low density case").

Two additional studies were conducted. Subjects were 40 (20 in each) children of native English speaking parents with no history of hearing loss or language delay. They had a mean age of 17.2 months. The hypothesis was that, in both experiment, words from the high-density/high phonotactic condition would be easier to learn than words from the low-density/low phonotactic neighborhoods.

2.1. Stimuli, Design, Apparatus, Procedure, and Coding

The stimuli, design, apparatus, procedure and coding were the same as in the previous study. However, infants only heard the high and low density lists one time through.

2.2. Results and Discussion

In contrast to the previous study, infants only learned the word in the high-density condition (see experiment 2, Table 3). That is they looked significantly longer at the target over the non-target in only the high-density condition, t (19) = 2.40, p = .01. They did so even if (instead of the neighbors) they heard the target word substituted in their place during familiarization (see experiments 3, Table 3), t (19) = 1.82, p = .04.

Thus, it appears that amount of exposure matters. 17-month-old infants briefly exposed to high-density neighborhoods learned the target word from this neighborhood better than the target word from the low-density neighborhood. This was most likely due to infants' sensitivity to probabilistic phonotactics rather than any neighborhood effect per se. In contrast, as infants were exposed more to the neighborhoods, a competitive effect was observed.

Thus, these results suggest a "U-Shaped" relationship between phonotactic effects and lexical density: Brief exposure to dense lexical neighborhoods produces benefits at the phonotactic level, facilitating the learning of new words. More prolonged exposure to dense lexical neighborhoods induces lexical competition, inhibiting the learning of new words.

Still unknown is how the individual frequency of items in the neighborhood and properties of the neighborhood might affect word learning. Nor do we know whether some neighbors are more important than others. Perhaps words that begin the same way have a greater effect than those that share a rhyme?

In any case, it bears noting that the effects observed were due to prior exposure to similar sounding words. Training & Test were identical for all studies. Thus, even before infants learn meanings, their acoustic memory and its similarity-based organization can affect their ability to learn new mappings.

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