

Frequency and form as determinants of functor sensitivity in English-acquiring infants

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Abstract: High-frequency functors are arguably among the earliest perceived word forms and may assist extraction of initial vocabulary items. Canadian 11- and 8-month-olds were familiarized to pseudo-nouns following either a high-frequency functor *the* or a low-frequency functor *her* versus phonetically similar mispronunciations of each, *kuh* and *ler*, and then tested for recognition of the pseudo-nouns. A preceding *the* (but not *kuh*, *her*, *ler*) facilitated extraction of the pseudo-nouns for 11-month-olds; *the* is thus well-specified in form for these infants. However, both *the* and *kuh* (but not *her-ler*) facilitated segmentation for 8-month-olds, suggesting an initial underspecified representation of high-frequency functors.

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PACS numbers: 43.71.Ft [JH]

Date Received: January 11, 2006 Date Accepted: March 27, 2006

1. INTRODUCTION

The production of an infant's first words is an achievement crowning months of perceptual work. One of the crucial perceptual tasks is the recognition of different acoustic realizations of a word in continuous speech. The speech which infants hear in the first year consists largely of continuous multi-word utterances,¹ in which word boundaries are not reliably marked and in which words may appear in varying phonetic environments. Nonetheless, during the first year of life infants gradually attune perception to the native phonemic repertoire,² acquire knowledge of acceptable versus unacceptable sequences of these sounds,³ and become sensitive to the probable patterns of words of their language.⁴ Construction of a vocabulary crucially depends on the ability to extract word forms from a continuous context. With a two-phase familiarization and test procedure, Jusczyk and Aslin⁵ demonstrated this extraction ability in prelinguistic infants; with the same type of procedure, the cortical responses to the occurrence in continuous speech of a form previously heard in isolation were observed.⁶ Since the first demonstration of noun segmentation,⁵ many subsequent studies⁷ have examined numerous aspects of content word segmentation.

Function words offer—at least in English and similar languages—a possible aid to infants in this task. More than half of English spontaneous speech consists of functors (e.g., determiners and conjunctions).⁸ There are few functor types, so the frequency with which each occurs is high. The high frequency of functors facilitates grammar acquisition in adults' learning of artificial languages.⁹ We here inquire whether they may also facilitate, early in language acquisition, the segmentation of potential vocabulary items from speech.

Certainly infants are acquiring sensitivity to functors in the period in which they are beginning to amass a vocabulary. Behavioral^{10,11} and ERP¹² evidence indicates that English-learning 10.5- to 11-month-old infants distinguish real from nonsense functors in continuous-speech contexts. Furthermore, infants at 11 and 13 months prefer real functors over minimally modified nonsense functors, suggesting that they recognize real functors with phonetically detailed representation.¹¹ German-learning 7- to 9 month-old infants¹³ and French-learning 6- to 8-month-old infants¹⁴ are able to segment function words from continuous speech. Note that German and French functors are phonologically stronger than English functors, which are predominantly weak.¹⁵ However, across typologically different languages infant-directed speech exhibits contrasting cues, acoustic as well as distributional, which support differentiation of functional from lexical elements.¹⁶

To examine whether functors facilitate segmentation of potential vocabulary items, we exploited the familiarity effects which appear in the two-phase familiarization and test procedures introduced into infant speech perception research by Jusczyk and Aslin.⁵ Infants express familiarity by listening longer in the test phase to known elements, usually items first presented in the familiarization phase. In a variation on this procedure we made familiarity dependent upon infants' ability to segment test items from a preceding functor. If infants are able to perform this segmentation, they will perceive the items presented in isolation in the test phase as familiar. However, if no segmentation occurs (i.e., functor and test item are perceived as an unsegmented whole), the test item when presented alone will be perceived as an unfamiliar form.

As described above, earlier work has shown that 11-month-olds can recognize the correct phonetic form of function words; we therefore began our study with 11-month-olds. Infants were first familiarized with pseudo-nouns preceded by either real or nonsense functors. In the test phase, they heard the same pseudo-nouns without the preceding context. As functor frequency is crucially involved in functors' facilitatory role in language acquisition,⁹ and as frequently encountered forms may prove particularly useful in segmentation,¹⁷ we reasoned that it would be important also to examine the frequency factor within the functor class. We therefore contrasted a high-frequency functor (*the*) with a functor with a lower frequency of occurrence (*her*). The difference between these two in the relevant speech type—speech to infants—was established in several corpora. In a corpus of 290 094 words (word types=50 855)¹⁸ of 11 parents speaking to their infants (aged 9 to 13 months; each recorded bi-weekly) the frequency of *the* was 8513, and of *her* was 307. Parental speech to infants up to 24 months of age in three further corpora^{19–21} yielded a total of 71 978 word tokens and 16 310 word types; in this total, the token count for *the* is 2484 and for *her* 114. Thus although all functor elements have relatively high frequency compared with content words, *the* is likely to have occurred far more often than *her* in the listening experience of infants.

2. EXPERIMENT 1

Twenty-four 11-month-old monolingual English-learning infants completed the task, 8 in the high frequency and 16 in the low frequency condition. Another 10 infants were tested but were excluded due to fussiness, equipment errors, or insufficient looking time during familiarization. Stimuli were the English functors *the* (high-frequency) and *her* (low-frequency), plus prosodically matched nonsense functors *kuh* and *ler*, which differed from *the* and *her* only in the onset consonants. Stimuli were analyzed for duration, amplitude, and pitch to ensure they were well matched. Both *her* and *ler* were produced with a rhotic /ɚ/ distinct from the schwa in *the* and *kuh*. Both types of functors were paired with the pseudo-nouns *breek* [brik] and *tink* [tiŋk] to form 8 simple noun phrases, *the breek*, *her tink*, *ler tink*, etc. A native speaker of American English, a mother of a 6-month-old infant and naive as to the goal of the study, produced the stimuli in an infant-direct speech style. The final set of stimuli included three tokens of each of the eight sequences, and tokens of *breek* (15) and *tink* (15) in isolation.

During the familiarization phase, infants heard six alternating trials (3+3) of “functor+*breek*” and “nonsense functor+*tink*” (or “functor+*tink*” and “nonsense functor+*breek*”). They were then immediately presented with four test trials (two trials with isolated

breek tokens alternating with two trials of isolated *tink* tokens). All trials were 16 s. The inter-stimulus duration between sequences was 500 ms, with minor adjustments to maintain the same trial length despite slight durational variations among sequences. Orders and functor-pseudoword pairing were counterbalanced across infants, but the test order was constrained: if the last familiarization sequence contained *breek*, the first test trial began with *tink*, and vice versa.

In a sound-attenuated chamber the infant sat on his/her parent's lap facing a central TV monitor and a loudspeaker. During trials, auditory stimuli were presented together with a black-and-white checkerboard on the screen, using HABIT 2000.²² The parent heard masking music over headphones. The researcher in the next room, blind to the trial orders, observed the infant through a closed-circuit TV, and pressed a computer key whenever an eye fixation occurred. Each trial was initiated upon the infant's eye fixation. Once a trial was initiated, it continued for the entire trial length. All looks to the monitor were recorded online, and were subsequently rescored from videotape records at 30 frames/s; statistical analyses were based on the offline data. Infants who did not reach 15 s of cumulative looking time while receiving the 48-s exposure of each sequence type during familiarization were excluded from the analysis, to ensure that all infants gave sufficient attention to the sequences before the test phase.

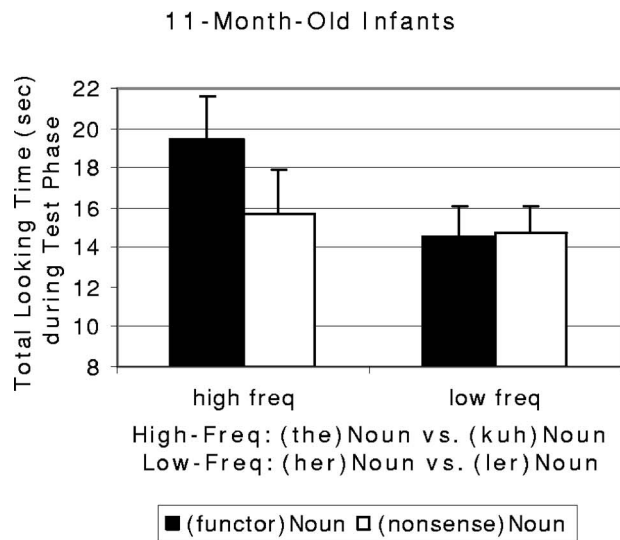
The comparison of interest is relative looking time to the display during presentation of each test pseudo-noun. If the first syllable (functor type) of the familiarization sequences is recognized as familiar, the pseudo-noun with which it is paired will be apprehended as a separate word form and will invoke longer looking time when it appears in isolation in the test phase.

Figure 1(a) shows the very clear pattern which appeared in this experiment. Pseudo-nouns which had been preceded by *the* in the familiarization phase elicited longer looking times than pseudo-nouns preceded by any other of the functor types. For each infant, we calculated the total looking time across *breek* and *tink* trials separately, and conducted a mixed 2×2 ANOVA with familiarization frequency (high, i.e., *the-kuh*, versus low, i.e., *her-ler*) as between-subjects factor, and familiarization functor type (real, i.e., *the-her*, versus nonsense, i.e., *kuh-ler*) as within-subjects factor. This revealed no significant main effect of frequency, but a significant main effect of functor type, $F(1, 22) = 8.038$; $p = 0.01$ (Mean = 16.96 s, SE = 1.36 s for pseudo-nouns previously paired with real functors; Mean = 15.21 s, SE = 1.24 s for pseudo-nouns previously paired with nonsense functors); further, the interaction between these factors was significant: $F(1, 22) = 10.139$; $p = 0.004$. Follow-up paired *t*-tests showed that infants listened significantly longer to pseudo-nouns previously familiarized with *the* (Mean = 19.41 s, SE = 2.18 s) than to those previously familiarized with *kuh* (Mean = 15.69 s, SE = 2.27 s), $t(7) = 3.9$; $p = 0.006$, 2-tailed. Every infant in this condition looked longer to *the* than to *kuh* nouns. In contrast, no difference was found in the low-frequency *her-ler* condition.

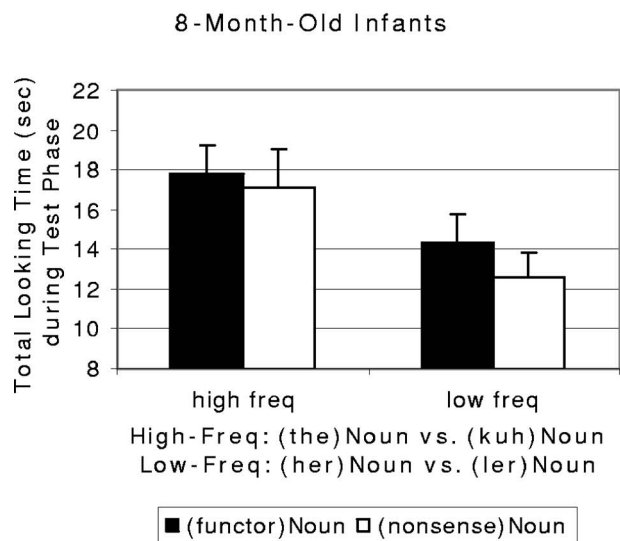
Infants' looking times during familiarization were analyzed in high- and low-frequency conditions; there was no difference between real versus functor sequences, and familiarization exposure was equivalent across the two frequency conditions.

The test phase results clearly indicate that the high-frequency real functor *the* allows 11-month-old English-acquiring infants to segment adjacent word forms from it. Less frequent real functors, and nonsense functors, are significantly less effective. Note that the high-frequency group, in which the pattern is statistically robust, had only half as many participants as the low-frequency group. Thus we can be confident that the failure to find a significant real-functor preference in the low-frequency group is not simply due to lack of power.

In Experiment 2 we repeated the task with younger listeners. In speech to 8-month-olds, *the* is also presumably the most frequent functor type. If frequency is the only determinant of the emerging sensitivity to functor identity, *the* may be equally effective for 8-month-olds.



(a)



(b)

Fig. 1. 11-month-old [(a), Experiment 1] and 8-month-old [(b), Experiment 2] infants' mean total looking time (with SEs) to pseudo-nouns in the test phase, as a function of familiarization functor type. In the high-frequency condition one noun was heard with *the* and another noun with *kuh* during familiarization, i.e., (*the*)Noun, (*kuh*)Noun. In the low-frequency condition the same nouns were heard with *her* and *ler*, respectively, during familiarization, i.e., (*her*)Noun, (*ler*)Noun.

3. EXPERIMENT 2

Twenty-four 8-month-old English-learning infants completed the task. Another five infants were excluded from data analyses due to fussiness, equipment failure, experimenter errors, or insufficient looking time during familiarization. Stimuli and design were as in Experiment 1.

Looking times during familiarization exposure to real versus nonsense functor sequences were compared; there were again no differences across the high- or low-frequency conditions.

The test data were analyzed as a function of familiarization condition, as in Experiment 1. There was no significant main effect of functor type and no interaction of functor type and frequency. However, as shown clearly in Fig. 1(b), there was a significant main effect of frequency: Looking time for pseudo-nouns was longer after familiarization with high-frequency than with low-frequency pairs ($F(1, 22)=4.56$, $p=0.044$; Mean=17.43 s, SE=1.52 s for pseudo-nouns previously paired with *the* or *kuh*; Mean=13.46 s, SE=1.07 s for pseudo-nouns previously paired with *her* or *ler*). In other words, when the data were collapsed across *the* and *kuh*, there was evidence of facilitation in the younger listeners' segmentation of the strings whereby the second element produced longer listening times in the test phase. No such effect was exercised by the lower-frequency pair *her* and *ler*, which differed by less than 2 s from each other and by more than 2 s from *the-kuh*.

4. GENERAL DISCUSSION

Our study has revealed that functors indeed assist young infants in segmenting potential word forms from continuous speech. The test words in this experiment were novel forms which the infants could not have already known. The infants were not yet active communicators; few 11-month-olds intentionally produce known words, and no 8-month-olds do. During the second half of their first year, though, infants are actively engaged in learning how to amass a stock of vocabulary items. The occurrence of function words can, we have shown, help them in this task. Constructing a memory representation of words in the mental lexicon requires first segmenting word-size chunks from longer utterances. The presence of a highly frequent, familiar functor assists the infants in treating the adjacent element as a separate word chunk.

Our results suggest it is not the syntactic function of the functors *per se* which exercises the helpful effect. It is, rather, the fact that they occur very frequently in speech (including infant-directed speech). In our study, the longest looking times were recorded to test pseudo-words which had been presented with preceding *the*, the most frequently occurring word in all written and spoken frequency counts of the English language. This functor appears to have occurred often enough in the infants' listening experience such that whenever it is heard, the speech material following it is segmented from *the* and treated as a candidate vocabulary item. Clearly, very high frequency is necessary for this effect, because the real functor *her*, although in absolute terms also a frequently occurring English word, does not facilitate segmentation in the same way either for 11- or for 8-month-olds. As our tallies of word frequency in speech input to infants showed, infants hear *her* very much less often than *the*. The facilitatory effect in segmentation is restricted, at this age, to items which occur very frequently indeed.

Besides the effect of frequency, we discovered a further effect which we would interpret as an effect of acoustic form. For 8-month-olds, not only *the* but also its near match *kuh* facilitated segmentation and thereby produced longer looking times to the pseudo-words presented in isolation. As earlier work had shown,¹¹ 8-month-olds cannot distinguish real from nonsense functors during word recognition; the earliest age at which English functor representation in phonetic detail is established is 10.5–11 months.^{10–12} It is thus no surprise to find that 8-month-olds do not distinguish *the* from *kuh* in this word segmentation task. What is surprising is that both *the* and *kuh* act as significantly more effective facilitators of segmentation for this age group than do *her* and *ler*. Our interpretation of this effect is that for the 8-month-olds, a representation of the highest-frequency form is already in place, but it is as yet acoustically underspecified. Since we only compared *the* with *kuh*, and in particular we did not test the other frequent functor *a*, we cannot make a precise statement about the range of forms which would satisfy this underspecified representation (any syllable with schwa, schwa plus any singleton onset, only acoustically weak onsets, etc.); however, the failure of *her* and *ler* to exercise the facilitatory effect suggests that the form of the underspecified representation has to be reasonably close to the acoustic form of *the* itself.

The difference between full vowels and reduced vowels (mostly schwa) is extremely salient in English; listeners find it acceptable to replace any full vowel by the same vowel with any other level of stress (e.g., the first syllables of *audience*, *auditorium*, and *audition*, with primary, secondary, and no stress, respectively, may be interchanged), but never tolerate full

vowels exchanging with reduced (e.g., the first syllable of *addition*).²³ Newborn infants are already capable of distinguishing between lists of English content words (which all must have at least one full syllable) and function words (which mostly consist of a monosyllable with a reduced vowel).²⁴ We suggest that our results indicate that this full-reduced distinction is useful to infants in the crucial work of acquiring a vocabulary. The frequent occurrence of functors with a reduced vowel (not only *the* but also *a*) allows for the early construction of an underspecified “functor” representation with a reduced vowel, and this underspecified representation serves to facilitate segmentation of potential vocabulary items from speech input. At 8 months, this is a useful aid in the beginnings of vocabulary acquisition. Accumulation of further experience makes formation of phonetically detailed functor representations possible; thus at 11 months, *the* facilitates segmentation but *kuh* no longer does. Our previous study¹¹ showed that a wider range of functors is represented in phonetic detail by age 13 months, so that we would predict that 13-month-old listeners in a two-phase experiment would be able to use *her* also in segmentation.

The task of bootstrapping a vocabulary from continuous speech input is a formidable one, but infants begin to accomplish it by the end of their first year of life. Our results shed further light on how they do this. Frequently occurring forms, perhaps at first represented without full specification, serve as a framework against which potential candidates for vocabulary membership may be identified and extracted.

ACKNOWLEDGMENTS

This research was funded by grants from NSERC and FQRSC to R.S., and NSERC and McDonnell grants to J.W., R.S. and J.W. also acknowledge support from Max Planck Society visiting research stipends. Partial reports of this work were presented at the XIVth and XVth Biennial International Conference on Infant Studies.

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