

BRIEF REPORT

Recognition and Representation of Function Words in English- Learning Infants

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We examined infants' recognition of functors and the accuracy of the representations that infants construct of the perceived word forms. Auditory stimuli were "Functor + Content Word" versus "Nonsense Functor + Content Word" sequences. Eight-, 11-, and 13-month-old infants heard both real functors and matched nonsense functors (prosodically analogous to their real counterparts but containing a segmental change). Results reveal that 13-month-olds recognized functors with attention to segmental detail. Eight-month-olds did not distinguish real versus nonsense functors. The performance of 11-month-olds fell in between that of the older and younger groups, consistent with an emerging recognition of real functors. The three age groups exhibited a clear developmental trend. We propose that in the earliest stages of vocabulary acquisition,

function elements receive no segmentally detailed representations, but such representations are gradually constructed so that once vocabulary growth starts in earnest, fully specified functor representations are in place to support it.

The distinction between content and function words is important in human languages. Content words—nouns, verbs, adjectives, and adverbs—are open-class words; that is, more can always be added to the language. There are very many of them (high type count), but most of them occur rarely (low token frequency). In contrast, function words—auxiliaries, determiners, and complementizers—are termed closed-class words because languages resist alterations in the set of such terms. In any language, and in any natural speech register, function words have a low type count, but a very high token frequency.¹ Although particular categories can be language specific (e.g., Mandarin has classifiers), the content–function distinction is putatively language universal. Previous research showed that this distinction is marked acoustically, phonologically, and distributionally in the speech infants hear in typologically quite different languages (Shi, 1996; Shi, Morgan, & Allopenna, 1998). Whereas content words are more complex in acoustical and phonological form, the spoken forms of function words tend to be minimized. Even newborn infants can categorically discriminate the two word classes² (Shi, Werker, & Morgan, 1999).

Studies of artificial language learning reveal that the content–function distinction significantly affects language learnability; for adult English speakers, at least, an artificial language grammar is virtually unlearnable without functional markers of grammatical structure (Green, 1979). Moreover, the markers' usefulness is greater the higher their frequency of occurrence relative to the content items of the vocabulary (Valian & Coulson, 1988). Acoustic realization of content elements as strong (e.g., with full vowels) but functional elements as weak (e.g., with reduced vowels) results in better learnability than any other realization of the content–function distinction (Cutler, 1993).

¹A computation of frequency of occurrences based on several infant-directed corpora in the CHILDES database (MacWhinney, 2000) revealed that this pattern is indeed true in this type of speech. We counted the total number of occurrences for the five functors used in our experiment: *the*, *her*, *his*, *their*, and *its*. In the Brent corpus, transcripts of 11 parents speaking to their infants (aged 9–13 months; total number of word tokens = 290,094; total number of word types = 50,855) the average type–token ratio of these functors was 1:1872.8, far higher than the average type–token ratio across all words of 1:5.7 (Brent & Siskind, 2001). We also calculated the combined total frequency counts for functors in the speech directed to children up to 2 years in the Bernstein corpus (Bernstein-Ratner & Pye, 1984), the Higginson corpus (Higginson, 1985), and the Bates corpus (Bates, Bretherton, & Snyder, 1988; Carlson-Luden, 1979). The total number of word tokens is 71,978, and that of word types is 16,310. The average type–token ratio for the five functors was 1:595.8, whereas the average type–token ratio for all words was 1:4.4.

²Although the term *words* in adult grammar refers to free morphemes, it is used here to refer to any reasonable “chunks” of potential vocabulary material, from the perspective of the infant.

The early ability to distinguish content and function words, and the demonstrated connection to learnability, make it plausible that language acquisition might be facilitated if infants focus on each of the two classes separately for detailed processing. Indeed, when content and function words are presented as different stimulus lists, infants attend more to content words (Shi & Werker, 2001, 2003). Infants recognize content words first (Jusczyk & Aslin, 1995; Mandel, Jusczyk, & Pisoni, 1995), and their early production is telegraphic; that is, functors omitted (Braine, 1963; Brown, 1973). However, this does not mean that infants overlook the (acoustically weaker) functors. In picture-naming and sentence-imitation tasks, 2-year-old children's performance is facilitated by the presence of functors (Gerken, Landau, & Remez, 1990; Gerken & McIntosh, 1993); 2-year-old Dutch infants and 18-month-old English infants show effects of functors in word comprehension tasks (Johnson, 2005; Zangl & Fernald, 2005). English-learning 10.5- and 11-month-old infants detect segmental changes that make nonwords of function items, in behavioral (Shady, 1996) and event-related potential experiments (Shafer, Shucard, Shucard, & Gerken, 1998). German-learning 7- to 9-month-olds (Höhle & Weissenborn, 2003) and French-acquiring 6- to 8-month-olds (Shi, Marquis, & Gauthier, 2006) segment function words from continuous speech; note that functors are less reduced in spoken forms in French and German than in English.

It is reasonable that function words, being highly frequent compared to content words, are among the earliest recognized word forms. However, whereas infants aged 8 to 14 months process fine phonetic detail of familiar content words in recognition tasks (e.g., Fennell & Werker, 2003; Jusczyk & Aslin, 1995; Swingley, 2005; Swingley & Aslin, 2002; Werker & Yeung, 2005), it is unknown whether they also process functors with phonetic detail. On the one hand, the high frequency of occurrence may make functors so familiar to infants that they are recognized in precise detail. On the other hand, functors tend to be reduced and cliticized in speech input (Cutler, 1993; Selkirk, 1996; Shi et al., 1998) and they rarely occur in citation forms; this may make their acoustic realization less precise than that of content words. The less precise realization may interfere with full encoding. Indeed, at 11 to 14 months even familiar content words can be confused with phonetically similar nonwords when the phonetic cues distinguishing them occur in weak rather than strong syllables (Hallé & de Boysson-Bardies, 1996; Vihman, Nakai, DePaolis, & Hallé, 2004), and acoustic degradation of content words makes recognition slower and less accurate (Zangl, Klarman, Thal, Fernald, & Bates, 2005). Moreover, functors and content words assume different syntactic and semantic roles. Functors appear as the "skeleton" for utterances, supporting thematic roles and phrase structure; their mapping of meaning to word form may be less straightforward than is the case for many content words (Gillette, Gleitman, Gleitman, & Lederer, 1999), and detailed specification of their phonological form may not be necessary at an early age. All these reasons may make the initial recognition of function words and content words follow different developmental trajectories.

This study thus sought to determine the age at which infants begin to recognize function words, and how they process the sound structure of function words. We tested infants at 13 months (when lexicon construction has begun), at 11 months, and at 8 months (both preverbal groups).

METHOD

Participants

Sixty monolingual English-learning infants participated: sixteen 13-month-olds, sixteen 8-month-olds, and twenty-eight 11-month-olds. Another 26 infants (i.e., eleven 13-month-olds, eleven 11-month-olds, and four 8-month-olds) were tested but were excluded from the analysis due to fussiness ($n = 11$), parental interference during experiment ($n = 3$), equipment or program errors ($n = 5$), overall looking time too short ($n = 5$), and experimenter error ($n = 2$).

Auditory Stimuli

Stimuli were five English functors: *the*, *his*, *her*, *their*, and *its* (of which *the* has highest frequency, *his* and *her* lower frequency, and *their* and *its* lowest), plus five nonsense functors matched to these: *kuh*, *ris*, *ler*, *lier*, and *ots*. The nonsense functors were prosodically analogous to the real functors, but differed segmentally. Four pairs differed only in initial segment; *lier/their* differed in initial consonant and vowel ([i] for *lier*). Because functors do not occur in isolation in natural speech, the real functors were each paired with a pseudo-content word *breek* [brik] and *tink* [tɪŋk] to form simple noun phrases³ (e.g., *the breek*, *his breek*, *their tink*, *her tink*, etc.). The nonsense functors were similarly paired with the pseudo-content words: *kuh breek*, *ris breek*, *kuh tink*, and so on. (Examples of stimuli are given at <http://www.psychology.utoronto.ca/GRL>). Using multiple functors enables assessment of infants' recognition of functors as a set, potentially illuminating processing patterns for functors in general. Although there are usually more content than function word types in natural speech, the use of two rather than

³The fact that function words hardly ever occur in citation form is worth further discussion. In general, function items, unlike content words, tend to be reduced and cliticized in spontaneous speech; even when the vowel is not schwa, the form as a whole is prosodically weak (Cutler, 1993; Selkirk, 1996; Shi, 1996; Shi et al., 1998). Our experiments presented infants with exactly these patterns: prosodically weak functors preceding prosodically strong content forms. Therefore, unlike many segmentation studies where target words, usually content words, were presented in isolation (e.g., Jusczyk & Aslin, 1995), our functors were not presented alone because they would sound unnatural. In a recent study, we tested segmentation and showed that 11-month-olds can segment function words from continuous utterances (Shi, Cutler, Werker, & Cruickshank, 2006).

many content words in this study makes the task simpler. The stimuli were produced in infant-directed register by an English-speaking mother who had a 6-month-old infant at the time of recording. She was blind to the purpose of the study. Multiple tokens of each phrase were used. The final stimuli were carefully chosen such that the nonsense functors overlapped in distribution with the real functors in prosodic properties (vowel duration, vowel center amplitude, and maximum pitch height), and the pseudo-content word tokens occurring in nonsense versus real functor contexts also overlapped in prosodic properties (see Appendix).

Several repetitions of a pseudo-word *neem*, produced by a (different) female speaker and converted to sine waves (Vouloumanos, Kiehl, Werker, & Liddle, 2001), served as stimuli for pre- and posttest trials, which were not part of the experiment; auditory stimuli differing from the test stimuli would not interfere with the experiment results. The pretest trial provided infants with a common baseline trial and familiarized them with the task. The posttest trial allowed us to assess whether infants were still on task. If so, looking time should recover, relative to the last experimental trial, on the infant hearing the highly distinct sine-wave stimuli.

Design

The experiment had two conditions: One contained “Real Functor + *breek*” and “Nonsense Functor + *tink*” sequences, the other, “Real Functor + *tink*” and “Nonsense Functor + *breek*” sequences. Infants were assigned randomly to these conditions.

Auditory stimuli were presented in six 16-sec trials. For Condition 1, three “Real Functor + *breek*” trials alternated with three “Nonsense Functor + *tink*” trials, with order of trials counterbalanced. Each trial presented multiple sequences of the same type—*the breek*, *her breek*, *his breek*, and so on. The five sequences of each of the two types were presented randomly but equally often. In Condition 2, “Real Functor + *tink*” and “Nonsense Functor + *breek*” trials were arranged in the same way. Intersequence duration was 500 msec, with minor adjustments to ensure that the trial length of 16 sec was maintained despite slight durational variations among sequences.

Procedure

We measured infants' looking responses to a central visual display (Cooper & Aslin, 1990), using Cohen's HABIT software (Cohen, Atkinson, & Chaput, 2000). The experiment was conducted in a sound-attenuated chamber. The infant was seated on a parent's lap in front of a TV monitor and a loudspeaker. During trials, the auditory stimuli were presented together with a visual display of a black-and-white checkerboard. The parent wore headphones delivering masking music. Each 16-sec trial was initiated on the infant's eye fixation. Once a trial was

initiated, it stayed on for 16 sec, regardless of whether infants looked away or not. Infants' looking time to the monitor during each trial was recorded online. The experimenter in an adjacent room, who was blind to the trial orders, observed infants' eye movements through closed-circuit TV and pressed a computer key whenever an eye fixation occurred. The testing software recorded look(s) within trials and calculated total looking time per trial. Participants with cumulative looking times of less than 10 sec per sequence type across the three trials were excluded. Test sessions were videotaped to allow for posttest frame-by-frame coding, necessary for verification of the online coding.

RESULTS

For each infant, we calculated mean looking time per trial across "Real Functor + Content Word" versus "Nonsense Functor + Content Word" trials. As is customary with this procedure, data were analyzed without the first trial, to remove effects of high variability associated with onset of testing (Cooper & Aslin, 1994; Cooper, Abraham, Berman, & Staska, 1997; Shi & Werker, 2001). We predicted that if infants could recognize real functors in phrases, their looking time should be longer for sequences containing real functors than for those containing nonsense functors. Furthermore, as the nonsense functors in our study were minimally modified from real functors, longer looking time to real functors would suggest that the functors were represented with detailed segmental specifications.

A mixed 3×2 analysis of variance, with age (13, 11, or 8 months) as between-subject factor and sequence type (real vs. nonsense functors) as within-subjects factor⁴ revealed a near significant effect of age, $F(2, 57) = 2.91, p = .063$; a near significant effect of sequence type, $F(1, 57) = 3.457, p = .068$; but a significant interaction of sequence type and age, $F(2, 57) = 3.464, p = .038$. Follow-up analyses for each age group showed no difference in looking time across sequence types for 8-month-olds, $t(15) = -.982, p = .342$ (real functors: $M = 12.083$ sec, $SE = .439$ sec; nonsense functors: $M = 12.573$ sec, $SE = .47$ sec); a tendency toward preference for real-functor sequences in 11-month-olds, $t(27) = 1.817, p = .08$ (real functors: $M = 11.122$ sec, $SE = .415$ sec; nonsense functors: $M = 10.479$ sec,

⁴With the first trial removed, the analysis compared average looking time per trial for the two sequence types over the remaining five trials. Comparable results were obtained if the initial two trials (i.e., one of each sequence type) were removed, to keep the number of trials balanced. Trend analyses also yielded a significant linear trend of age, and no quadratic trend. When we included all trials for analysis, however, we obtained a significant main effect of sequence type ($p = .024$), but no significant interaction of sequence type and age ($p = .191$). This overall effect of sequence type was likely due to the strong preference shown by the older age groups, as the t test with 8-month-olds alone (including the first trial) in fact showed equal looking time for the two sequence types ($p = .993$). The trend analysis including all trials yielded a tendency for a linear trend of age ($p = .071$), and no quadratic trend.

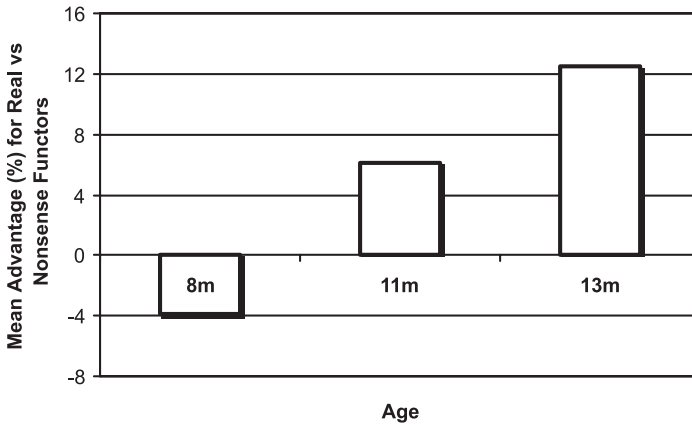


FIGURE 1 Mean percentage advantage in looking time across three ages for utterances with real functors over utterances with nonsense functors. Mean percentage advantage was calculated as follows: mean looking time for real functor utterances divided by that for nonsense functor utterances minus 1.

SE = .522 sec); and a significant preference for real-functor sequences in 13-month-olds, $t(15) = 2.507, p = .024$ (real functors: $M = 11.796$ sec, $SE = .562$ sec; nonsense functors: $M = 10.485$ sec, $SE = .556$ sec).

A trend analysis was conducted by taking the differential score of real versus nonsense functor trials for each infant across all three age groups. This revealed a significant linear trend ($p = .012$) across the three ages, and no significant quadratic trend. Effect size analyses revealed that the 11-month-olds' preference for real functors corresponded to a medium effect size in Cohen's standard (Cohen's $d = .3$; effect size $r = .1$), whereas 13-month-olds' preference constituted a large effect size (Cohen's $d = .6$; effect size $r = .3$).

These results indicate progress between 8 and 13 months; indeed, the 11-month-olds' performance falls neatly between that of the older and younger groups. Figure 1 shows the mean percentage advantage in looking time for real versus nonsense functor sequences across the three ages. The mean advantage for the 11-month-olds falls between the null effect for the 8-month-olds and the robust effect for the 13-month-olds. A numerical preference for real over nonsense functors was shown by 37.5% of 8-month-olds, 57.14% of 11-month-olds, and 75% of 13-month-olds.

A final analysis compared looking time in the first versus the second half of the trials (see Vihman et al., 2004), using all trials (including the very first trial). At 13 months, infants looked significantly longer to real than to nonsense functors in both the first half, $t(15) = 2.54, p = .04$, two tailed, and second half, $t(15) = 2.16, p = .047$, two tailed, of the trials. At 8 months, there were no significant

differences in looking time in either half. However, at 11 months, although infants did not look longer to real than to nonsense functors during the first half, they did during the second half, $t(15) = 2.065$, $p = .049$, two tailed. This may indicate a slower speed of processing or recognition in 11-month-olds than what 13-month-olds could command. Thus the recognition and representation of function words seems to develop gradually across the three ages tested in this study.

GENERAL DISCUSSION

Our results suggest that English-learning infants recognize function words and represent them in phonetic detail in the early lexicon by 13 months of age. At that age, infants preferred to listen to real functors over minimally segmentally modified nonsense functors. At 8 months of age, in contrast, infants did not distinguish real from nonsense functors. At 11 months, infants showed an intermediate pattern of performance. The process of learning to recognize function words is thus a gradual one.

Our results with natural speech complement Shady's (1996) and Shafer et al.'s (1998) demonstrations with synthetic materials (and different procedures) that English-learning 10.5- to 11-month-olds could detect alterations to functor forms. Shady (1996) and Shafer et al. (1998) also used nonsense syllables that differed completely from real functors (i.e., within a given syllable, neither the onset, nor the rime, nor the coda overlapped with the real functor matched to it; only one item contained a partial overlap with the matched real functor). Our nonsense functors were, besides being naturally spoken, also naturally "functor-like," in that they had only minimal segmental changes from their matched functor forms, and they maintained the unstressed prosody of functors. Thus our comparison allowed us to assess the detail with which young listeners recognize and represent functors. Our 11-month-olds showed recognition and detailed representation by the second half of the trials, and the 13-month-olds showed robust performance from the beginning of the experiment. The advance from delayed to immediate recognition between 11 and 13 months of age is an indication, we believe, that 11 months is a transitional period in the development of infants' knowledge of function words.

The finding that 8-month-old infants do not show a preference for real over segmentally modified functors is of particular interest. This null effect is unlikely to reflect lack of task sensitivity. Spontaneous preference tasks have been successful in showing infants' sensitivities to subtle phonetic and phonotactic differences (e.g., Jusczyk, Friederici, Wessels, Svenkerud, & Jusczyk, 1993). Although this null effect could imply that 8-month-olds cannot apprehend function words at all, it is also plausible that they might apprehend functor presence, but fail to distinguish real from modified functors, especially when, as here, the two are similar. Indeed, other work shows that infants around this age seem to be tuning into

the most likely word shape for their language. Jusczyk, Cutler, and Redanz (1993) found that 9-month-olds significantly preferred initially stressed (*former, curdle*) over initially weak disyllables (*inform, occur*). Six-month-olds showed no such form-based preference within content words; thus the preference develops between 6 and 9 months. Most English words have initial stress (Cutler & Carter, 1987), so the 9-month-olds preferred the forms more typical of English. Jusczyk, Cutler, et al. (1993) argued that infants develop an abstract representation of what words are most likely to be like as an aid to vocabulary acquisition. Our experiments, likewise, presented infants with exactly the patterns typical of functor occurrence in English: prosodically weak functors preceding prosodically strong content forms (Cutler, 1993; Selkirk, 1996; Shi, 1996). Thus the preference that we observed was for the typical pattern of English, and we argue that infants are developing an abstract representation of what functors are like—prototypically, a weak monosyllable. The functors in our set match this prototype, but so do the prosodically analogous nonsense functors; although our older listeners could distinguish the two sets, for our 8-month-old listeners, the two sets may have been effectively equally prototypical.

How would a functor prototype be developed? We suggest that recognition of such a prototype may arise from accumulated frequency of individual types of these words reaching a criterial threshold over a period of time in speech input. Functors as a class are highly frequent compared to content words (see footnote 1). The total frequency of each individual functor type may initially be insufficient to motivate a definite representation, but the joint frequency of the monosyllabic functors with weak stress could prompt an abstract representation with this form. Further experimental work is required to distinguish our preferred interpretation from the alternative interpretation that infants at 8 months know nothing at all about functors.

As noted, the course of acquisition of functors and content words may differ, so that there is no necessary conflict between our demonstration of detailed phonetic specification only by 11 to 13 months, and the previous work suggesting that content words are recognized with detailed phonetic specification from earlier ages (e.g., Bortfeld, Morgan, Golinkoff, & Rathbun, 2005; Jusczyk & Aslin, 1995). Functors are reduced in speech, which itself may delay their acquisition; also, understanding of functor use depends on semantic and syntactic factors that are not yet likely to be important for younger infants. Overgeneralizing function words to a unitary prototype at 8 months not only seems affordable, but also may ultimately be shown to help bootstrap language learning.

In sum, this work reveals that the recognition and representation of function words develops gradually in preverbal English-learning infants. Furthermore, we show that phonetically fully specified functor representations are in place by the end of the first year. Detailed recognition of function words may assist infants' further analyses of syntax and learning of new content words.

ACKNOWLEDGMENTS

This research was funded by a Natural Sciences and Engineering Research Council (NSERC) Discovery grant to Rushen Shi (RGP1261500), and by both an NSERC Discovery Grant (RGP81103) and Canada Foundation for Innovation (CFI) Grant to Janet F. Werker. Rushen Shi and Janet F. Werker also acknowledge support from Max Planck Society visiting research stipends. Partial reports of this work were presented at the 15th International Congress for Phonetic Sciences and at the 75th Acoustical Society of America meeting. We thank Carla Merkel, Marisa Cruickshank, and David-Étienne Bouchard for research assistance, and we thank all the parents and infants who participated in the study.

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APPENDIX
Mean Acoustic Values Across Multiple Stimuli Tokens

	<i>Duration (ms)</i>	<i>Max Amplitude (db)</i>	<i>Max Pitch (Hz)</i>
Real functors (f)	196.65	78.56	271.3
Nonsense functors (n)	214.82	78.06	279.14
Pseudo-noun following f	492.08	82.97	669.28
Pseudo-noun following n	493.24	81.5	654