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The Impact of Function Words on the Processing and Acquisition of Syntax

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Jessica Peterson Hicks

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ABSTRACT

The Impact of Function Words on the Processing and Acquisition of Syntax

Jessica Peterson Hicks

This dissertation investigates the role of function words in syntactic processing by studying lexical retrieval in adults and novel word categorization in infants. Christophe and colleagues (1997, in press) found that function words help listeners quickly recognize a word and infer its syntactic category. Here, we show that function words also help listeners make strong on-line predictions about syntactic categories, speeding lexical access. Moreover, we show that infants use this predictive nature of function words to segment and categorize novel words.

Two experiments tested whether determiners and auxiliaries could cause category-specific slowdowns in an adult word-spotting task. Adults identified targets faster in grammatical contexts, suggesting that a functor helps the listener construct a syntactic parse that affects the speed of word identification; also, a large prosodic break facilitated target access more than a smaller break. A third experiment measured independent semantic ratings of the stimuli used in Experiments 1 and 2, confirming that the observed grammaticality effect mainly reflects syntactic, and not semantic, processing.

Next, two preferential-listening experiments show that by 15 months, infants use function words to infer the category of novel words and to better recognize those words in continuous speech. First, infants were familiarized to nonwords paired with a determiner or auxiliary. At test, novel words occurred in sentences with a new functor of the same category as familiarization, or with an inappropriate functor. Infants listened longer to sentences in which the nonword occurred with a functor of the familiarized category. Next, infants were

familiarized to passages containing sentences from the previous task. At test, they heard an appropriate or inappropriate functor paired with the familiarized nonwords, as well as an unfamiliar distractor. Infants listened longer to nonwords when paired with a functor of the familiarized syntactic category, suggesting that, like adults, they recognized targets better when these matched their syntactic expectations.

Together, this experimental evidence underscores that information used by adults to predict syntactic structure on-line is also used by infants to build grammatical categories. This indicates that a theory of acquisition should prominently feature knowledge of functor co-occurrence patterns as a bootstrap into grammatical categories.

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CHAPTER 1

One of the chief questions in the study of language acquisition is how children learn the words of their native language from the unbroken stream of speech they receive as input. The fact that children rapidly learn to recognize and produce many words before their second birthday, without being taught each word explicitly in isolation, shows us that they are very adept at this despite the complexity of the task. The fact that children learn the words of whatever language they are exposed to shows they can perform this task without advance knowledge of what those words should be, and are sensitive to the properties of the input they receive.

Children's success at learning words is impressive, given the apparent difficulty. The information they must extract from the speech signal to impute the beginnings and the ends of words is variable and noise-ridden. Yet, very young infants have been shown to perceive and exploit regularities in the prosodic, phonological, and distributional elements of speech that must serve as their entry into the word-learning problem. This leads us to ask what precise mechanisms are available to young children that permit such robust learning in the face of great variability in the learning environment.

The task of identifying words is only a first step in the larger problem of learning a first language. Young children must also engage in analyzing and classifying the bits of language they have parsed from the speech stream, in order to build the grammar appropriate to their language. The classification of words into categories such as nouns, verbs, adjectives, and prepositions, is essential to the arrangement of these fundamental categories into larger syntactic units, such as phrases, clauses, and sentences. Contemporary generative syntax holds that the phrase structure of a grammar encodes syntactic constituents, which are hierarchically organized and labeled according to category. Therefore, knowledge of these categories is an important initial step in building phrase structure. The question is then, how do children learn to categorize the words that they are busy acquiring? They need to identify a source, or multiple sources, of information that they can bring to bear on grouping words into categories.

One proposed source of useful information about how to group words into categories is the very observation of how words are combined in the phrase structure of a language, or at least their co-occurrence relations with other words (Bloomfield 1933, Harris 1951, Maratsos and Chalkley 1980, Pinker 1984, Landau and Gleitman 1985). To say that children need to know about syntax to group words into categories, but also that they need to learn grammatical categories to build syntax, is a circularity known in the acquisition literature as a *bootstrapping problem* (Pinker 1987). Proposed solutions to this type of problem will be discussed later in this chapter. However, it is just the recognition of the need to discover a useful bootstrap into grammatical category acquisition that lies at the heart of this dissertation.

In this dissertation, I examine the usefulness of the function words determiners and auxiliaries as a bootstrap into grammatical category acquisition. Since infants may learn to recognize these words via a combination of sound-based and distributional information (Jusczyk and Kemler Nelson 1996, Gerken 1996, Morgan, Allopenna, and Shi 1996 *inter alia*), evidence that infants use function words to bootstrap category acquisition supports the idea that infants can begin to solve the circularity problem without first having to learn the meanings of words (Landau and Gleitman, 1985; Gleitman, 1990). If this is the case, infants may begin building grammatical categories as soon as they are able to accumulate that type of relevant information, such as learning to recognize and compile a list of function words. This dissertation examines evidence for this type of hypothesis.

Even if we adopt the premise that all languages share the same prototypical grammatical categories (Baker 2005), the specific distributional information a particular language selects to separate grammatical categories varies tremendously. This makes the task of acquiring language-appropriate categories more than trivial. For infants to address this problem, Shi (2005) has proposed that they may begin by making a rudimentary category distinction between function words and content words, based on the universal properties of these two basic word classes. Such properties, which in combination may permit infants to recognize function words in continuous speech, include length, duration, pitch, low type frequency, vowel reduction, and more (Morgan 1996, Shi, Morgan, and Allopenna 1998). Furthermore, these properties of function words available in the speech signal have been found to be roughly consistent across languages (Shi et al, 1998), which means that learners of many different languages may be able to use these properties in the same way at the same age.

When infants begin to recognize the function words of their own language, they may start compiling them into list. From such a list they can begin to notice co-occurrence patterns, for example, that function words often appear adjacently or in fairly regular distributional relationship to the other broad category of words, content words, and furthermore that certain function words only occur with certain content words. On this logic, knowing the function words of their language could give infants an advantage both in recognizing the content words that co-occur with them, and in construing a grammatical category to assign to a particular content word (Braine 1987, Christophe and Dupoux 1996). This process could allow infants to begin to divide and conquer content words into the grammatical categories appropriate to their language's grammar.

The first key to justifying this account is determining whether young infants are actually able to recognize function words, since they do not begin to produce grammatical morphemes until they are about two years old (Brown 1973, de Villiers and de Villiers 1973). Indeed, research has established that young infants do recognize function words, even before they are able to produce them (Shipley, Smith, & Gleitman 1969; Gerken, Landau, & Remez 1990; Gerken & McIntosh 1993; Shady 1996; Shafer, Shucard, Shucard, & Gerken 1998; Santelmann & Jusczyk 1998; Shady & Gerken 1999; *inter alia*). This evidence sets the stage for discovering how children younger than two years old may use their knowledge of function words to build grammatical categories, a capacity explored by experiments reported in this dissertation.

In order to draw parallels between infant language acquisition and adult lexical access and enrich models of both processes, we assume that prosodic and distributional information that is robust enough to be perceived and exploited by babies should be equally available to adults. Conversely, information that adults exploit regularly should be examined for its usefulness to learners as well. Even accepting the possibility that some acquisition strategies are later discarded in favor of more efficient strategies, the same information used during acquisition may continue to be highly useful to the adult parser. A sound assumption is that if robust regularities exist in the signal, they will be used to some extent in perception by both children and adults.

Related to this issue is how adults may use the properties of function words to predict syntactic structure on-line. As a preliminary, it is valuable to discuss the proposed mechanics of real-time syntactic structure building as explored by research on adult sentence processing. The literature on syntactic structure prediction has focused on studies that test how the human language parser treats certain well-known aspects of the underlying syntactic representations of sentences on a theory of transformational grammar (Chomsky 1965, 1973), such as how the parser might complete long-distance dependencies like gaps created by movement operations (Crain and Fodor 1985, Stowe 1986, Aoshima, Phillips, and Weinberg 2004); how it might deal with island constraints that block such dependencies (Phillips and Wagers 2005), and grammatical restrictions such as binding constraints and constraints on backwards anaphora (Sturt 2003, Kazanina, Lau, Lieberman, Yoshida, and Phillips in press). This research will be discussed in further detail, in connection with the studies reported here, in Chapter 4. All have been concerned with relating syntactic violations with some psycholinguistic index of processing difficulty, such as slower reaction times, a judgment of implausibility, evidence of reanalysis from eyetracking measures, the P600 waveform in ERP studies, among other measures. Recent studies find increasing evidence for nearly immediate effects on the time course of syntactic processing (Lau, Stroud, Plesch, and Phillips 2006), continuing to paint a picture of syntactic structure building which occurs rapidly and incrementally as a sentence is processed. This evidence on the time course of syntactic structure building relates to the current study in terms of the adult word-spotting studies reported here. Evidence that the parser makes rapid predictions about upcoming syntactic structure fits with the findings of the current study, that adults use the properties of function words to make rapid predictions about the grammatical category of an upcoming function word.

Other recent research related to the current study (Christophe, Guasti, Nespor, Dupoux, and Van Ooyen 1997; Christophe, Millotte, Bernal, & Lidz in press) has shown that adult listeners use both the properties of function words and their knowledge of phonological phrase boundaries to constrain on-line lexical access as well as on-line syntactic structure-building.

These studies propose that both infants and adults construct a pre-lexical representation that contains phonetic and prosodic information, and suggest that infants may build a partial syntactic structure using both phonological phrase boundaries and function words. An adult experiment reported in Christophe, et al (in press) supports this hypothesis: in a task involving detection of words of specific grammatical categories, French adults used phonological phrase boundaries to define syntactic boundaries and also used function words to label these constituents as noun phrases or verb phrases, thereby inferring the syntactic category of the nonsense target words. Children in the early stages of production, without a large vocabulary of content words, may also be able to perform a similar syntactic analysis using just their knowledge of function words and prosodic boundaries (Gleitman and Wanner 1982, Christophe and Dupoux 1996, *inter alia*).

This dissertation explores children's ability to perform such a syntactic analysis, and compares it to adults' performance on tasks requiring on-line lexical access modulated by the grammaticality of a preceding function word. The experiments reported here show that one particular piece of the information used by adults to anticipate syntactic structure in the incoming speech stream is also used by infants to discover syntactic structure. This finding leads to a further important conclusion, that a robust source of predictive information available in the signal is used for different types of analyses by listeners and learners.

1.1 Introduction: The acquisition problem

By 18 months, infants are fairly proficient at word recognition and are capable of processing speech incrementally in much the way that adults do (Fernald, McRoberts &

Swingley 2001). But in order to acquire that first vocabulary, infants must first succeed at the complex task of recognizing what words in their language are.

Research of the past 20 years has established that infants of an age that was once termed "pre-linguistic" have already taken strides toward solving the *segmentation*, *labeling,* and *bracketing* problems of acquisition (Gerken, Landau, and Remez 1990; Morgan 1996). That is, despite the continuous stream of speech input they are exposed to, young infants find ways to identify units in the signal, to distinguish between different types of these units, and to group these units together to build a grammar of their native language.

1.2 Mechanisms of grammatical category acquisition

1.2.1 Segmentation

In order to recognize words, infants must first become skilled analyzers of the acoustic and phonetic information they can perceive in the speech signal. The ability to detect sound patterns in the signal is the first prerequisite to word recognition, and can develop before an infant associates any of the sound patterns with a particular meaning (Fernald et al. 2001). Jusczyk and Aslin (1995) found evidence that infants have already developed the ability to segment words by the age of 7.5 months. Their study showed that infants listened longer to isolated words, like *cup* and *dog,* when they were previously familiarized to longer passages containing these words. Jusczyk and colleagues went on to find that infants at this age not only are capable of extracting monosyllabic words, but also bisyllables and trisyllables (Houston, Santelmann, and Jusczyk 2004). During this time period, between six and nine months of age, infants develop sensitivity to phonotactic and prosodic features of words.

Sensitivity to the prosody and phonotactics of their native language is probably a useful tool for word learners to cultivate, because many studies have shown that this information is rich in potential cues to the locations of word boundaries. In English, for example, the majority of multisyllabic content words begin with strong syllables, giving a reliable cue to the onsets of words that adult listeners have been shown to use as a segmentation strategy (Cutler and Norris 1988; McQueen, Norris, and Cutler 1994). Knowledge of native phonotactic patterns that occur more often at word boundaries than within words, as well as of the distribution of contexts in which one syllable is likely to follow another, have been shown to be sources of information about word boundaries that listeners may use for segmentation (Brent and Cartwright 1996).

Demonstrating that not only is such information readily available, but that infants use it for segmentation, Mattys, Jusczyk, Luce, and Morgan (1999) and Mattys and Jusczyk (2001) showed that babies use phonotactics to make an elementary segmentation of the speech signal into words. Mattys et al (1999) found that 9-month-olds relied more on stress than on phonotactics to segment non-words containing consonant clusters. Mattys and Jusczyk (2001) found that 9-month-olds are better at segmenting words from contexts with good phonotactic cues to boundaries than from phonotactic contexts less likely to indicate a word boundary.

Evidence that infants less than a year old can exploit and even remember information about sound patterns of words is a strong indication that infants are involved in the task of identifying words well before they know the meanings of all the words they are learning to recognize (Johnson, Jusczyk, Cutler, and Norris 2003).

1.2.2 Categorization

In addition to learning how to recognize words, infants must discover how to group them into form classes or categories. Word categories, for instance nouns, are defined distributionally as the group of all words that can occur in the same grammatical contexts as other nouns. The grammatical contexts themselves are made up of other types of categories, like determiners, adjectives, and verbs, so that each category is defined in reference to some of the others. The following studies, among others, have tested whether words can be classified on the basis of distributional information. Distributional information may include the location of a particular word in a sentence, phonological properties such as where stress falls on a word or the phonotactic characteristics that correlate with word boundaries, or most relevant to the current study, marker elements, for instance functional morphemes such as determiners and inflectional markings for case, gender, and verb tense.

With respect to the major categories of noun and verb, at least three types of cues to the differences between major categories have been identified that may help learners break into this circularity: positional information, phonological properties of the categories, and grammatical morphemes (Gerken 2001).

1.2.2.1 Positional information

Positional information refers to the observation that nouns occur in certain lexical contexts and verbs occur in others. The following studies explore the feasibility and efficiency of categorization using positional information, examining the size of the frame necessary to most efficiently categorize words, be it a preceding word or multiple preceding words, trigrams of words that frequently co-occur with just one word to be categorized intervening, or entire sentences that frame a word to be categorized.

Valian and Coulson (1988) tested how bigram distributional information could contribute towards categorization. They constructed two types of artificial languages consisting of two categories A and B. In one language, words in a category (6 words each) were always preceded by the same high frequency marker word, so in sentences A words were always preceded by the word a, and B words were always preceded by the word b. In the other language a greater number of marker words were used, corresponding to smaller sets of A and B words. For each language, a group of participants was trained on a large set of sentences, then tested on a small subset. Some of the testing subset items violated the relationships of the marker word and the category that were evident during the training phase. Performance was quicker and more accurate for participants who had learned the language with high-frequency markers. The authors interpreted the high-frequency words in the artificial language as anchor points for determining the structure of the language. The ease of learning the language was measured by the frequency of the marker words.

Cartwright and Brent (1997) conducted a corpus study that identified pairs of sentences that differed in only a single word. This resulted in grouping the words that differed into a category, creating a template for a context in which a particular category would occur. They tested their model on a child-directed speech corpus from CHILDES and classified framed words at a high level of accuracy (68%), meaning rate of correct categorization, but a lower rate of completeness (22%), meaning the percentage of all the words in the corpus that were able to be categorized.

Redington, Chater, and Finch (1998) chose as a frame the local contexts of the most frequent 1000 words in the CHILDES corpora of child-directed speech. For each word, its co-occurrence with the 150 most frequent words was counted at positions of several words before and after. This information was combined to create clusters of cooccurrence vectors for words grouped on similarity. The success of the categorization was checked by labeling words with their grammatical category, and comparing these labels to the categorizations performed by the cluster analysis. The authors achieved an overall word classification accuracy of 72% with completeness of 47%. One interesting feature of this study is that no information about category was included prior to the computation. This provides an interesting counterpoint to the studies discussed above (e.g. Valian and Coulson 1988) because the grammatical categories were constructed without prior knowledge of the categories. In addition, this study showed that words both preceding and following a word can be used to productively categorize it.

Mintz, Newport, and Bever (2002) performed a similar study, conducting analyses on corpora of speech directed to children less than 2.5 years old. They showed that by looking at the immediate lexical contexts of words, such as 1-, 2-, and 8-word contexts, the similarity of the contexts is sufficient to cluster words into basic categories of noun and verb. Building on this idea, Mintz (2003) showed that "frequent frames," or sets of two words that most frequently occur together with one word intervening, can be used as a powerful predictor of syntactic category. Mintz selected the 45 most frequent frames from six corpora in the CHILDES database (MacWhinney 2000) to perform a computational analysis of word category over the corpora. The analysis categorized words from a range of classes including nouns, verbs, adjectives, pronouns, adverbs, and auxiliaries with a mean accuracy of over 90 percent. The classification was achieved by analyzing only 5-6% of the tokens to successfully categorize about 50% of the tokens in the corpora overall. That is, the information provided by frequent frames in child-directed speech is both robust and produces highly accurate categories of words.

However, Monaghan and Christiansen (2004) conducted a study to compare the effectiveness of frequent frames (pairs of words that frequently occur with one intervening word) examined by Mintz (2003) in corpus classification versus a bigram in which new words would be classified only on the basis of the immediately preceding word. The authors found that using the smaller, less specific two-word frame also achieved high accuracy in classifying the words in the corpus, with the additional advantage of a much higher rate of completeness over the corpus.

Peña, Bonatti, Nespor, and Mehler (2002) familiarized adult French speakers with strings of trisyllabic synthetic nonsense words, then found that subjects were only able to extract grammatical-like generalizations to identify new words that fit the “rule” structure of the language when short pauses were inserted between words in the synthetic language. This study showed that listeners can use discontinuous frames to perform powerful statistical computations to segment artificial language strings, but only perform a higher-level algebraic computation to infer a category for a string when the frames are used in combination with a prosodic cue to segmentation.

The above studies demonstrate the usefulness of positional information for creating categories in adult experiments; it is naturally of concern to find direct evidence that infants can perform categorization based on the same type of information. As a few examples, the following two studies demonstrate that infants can use positional information to categorize words; further evidence for infants’ use of positional information in combination with marker elements to build categories is reviewed in Section 1.2.2.3.

Santelmann and Jusczyk (1998) showed that infants also attend to frames in speech, combining that information with attention to grammatical morphemes to demonstrate sensitivity to discontinuous verb-auxiliary dependencies. 18-month-old infants, but not 15-month-olds, listened longer to natural passages containing grammatical dependencies like *John is* run*ning* than to unnatural passages containing sentences like *John can* run*ning*. 18-month-olds continued to prefer the natural passages even when a two-syllable adverb separated the auxiliary from the-*ing* grammatical morpheme, though they stopped showing this preference when longer adverbials were inserted.

Gomez and Lakusta (2004) performed a related study with 12-month-old infants, in which they familiarized the infants to artificial language items consisting of pairs of monosyllabic marker elements, and word-like elements containing either one (Y elements) or two syllables (X elements). In test trials, the infants heard the same marker elements paired with new, unfamiliar wordlike elements of either the X or Y type. They found that infants listened longer to strings from the training language, indicating that the infants had categorized the novel words and distinguished the test items' grammaticality based on their co-occurrence with the marker items paired with each category during familiarization. This study demonstrated that by 12 months, infants already have the ability to generalize categories based on the co-occurrence of functional elements with two word types distinguished by a single feature.

In summary, the studies reviewed above present evidence that observation of positional relations of functional elements with content elements is a reliable predictor of grammatical category and can be used by language-learning infants.

1.2.2.2. Phonological differences between word categories

Kelly (1996) identifies a number of phonological properties that are highly predictive of grammatical category, including the findings that English nouns and verbs differ in stress pattern, duration, and syllable structure. Black and Chiat (2003) comprehensively review the phonological differences that distinguish English nouns and verbs, noting that English verbs are generally shorter, lack phonological prominence, and are more likely to have a non-canonical stress pattern relative to English nouns. These reliable phonological differences may be used by learners trying to group words into categories prior to discovering how to syntactically label these categories.

Durieux and Gillis (2000) performed a computational analysis to classify 5,000 disyllabic nouns and verbs drawn from the CELEX dictionary (Baayen, Piepenbrock, and van Rijn 1993). The classification criteria included phonological and prosodic properties, such as location of word stress, length measured by grouping phonemes into onset, nucleus, and coda; vowel and consonant quality, and total number of phonemes. Stress was the most successful individual predictor of word class, with 66.2% accuracy over all word forms in their database. The most successful analysis that Durieux and Gillis performed combined stress, marked for each item as primary, secondary, or none; and a segmentation of the phonemes divided into onset, nucleus, and coda. Using only these factors over all word forms in their database, their algorithm was able to classify 76% of nouns and 71% of verbs accurately.

Mattys and Samuel (2000) found evidence that adults are indeed sensitive to such available phonological differences between word categories, tending to read disyllabic pseudowords with stress on the first syllable if the word occurred in a syntactic context where a noun would be expected, and with stress second where a verb would be expected.

In summary, the studies reviewed above show that perception of a variety of phonological properties such as stress, length, syllable structure, may serve as a reliable predictor of grammatical class. Given that this information is robustly available and that adults have been shown to use it to predict category differences, we assume that infants may well be able to exploit the same information.

1.2.2.3. Grammatical morphemes

Gerken (2001) notes that of all the acoustic information available in the input for distinguishing syntactic categories, nearly every theory of acquisition gives a role to grammatical morphemes like function words. Individual phonological, statistical, and prosodic properties of function words have been shown to be consistently available across languages, cues that when clustered together can predict a restricted list of co-occurring content words (Morgan, Shi, and Allopenna, 1996).

The distinction between content and function words has been demonstrated on many dimensions of human languages. Content words, such as nouns, verbs, adjectives, and adverbs, are open-class words, which means they belong to a language class which always accepts new additions. In contrast, the functional elements of language, including auxiliaries, determiners, complementizers, and some prepositions, are closed class words, meaning languages do not easily admit changes to this set. This restricted nature of the class of function words is a consequence of its role in encoding grammatical structure. Furthermore, its restricted nature is one of the properties that makes it useful in classifying content words; noting co-occurrence relationships between function words and content words is a more efficient way to classify content words than by noting their co-occurrences with other content words (Gleitman, Gleitman, Landau, and Wanner 1988). Function words have a low type count, but a high token frequency. Although some categories are language-specific (for example, Mandarin Chinese has classifiers while English does not), it has been argued that the basic content-function distinction is a universal property of languages (Morgan, Shi, and Allopenna 1996, Shi 2005).

Shi, Morgan, and Allopenna (1998) analyzed the prosodic characteristics of function and content words in Mandarin and Turkish caregiver speech. For each caregiver group, they looked at distributional and phonological properties of content and function words like type frequency, utterance position, number of syllables, vowel duration, relative amplitude, and pitch change. The authors found that no one property was a strong predictor of grammatical category, but taken together they could predict grammatical category with a level of accuracy around ninety percent.

The morphosyntactic classes of the function words they analyzed include auxiliary verbs (including items marking tense, aspect, and voice), case or gender markers, complementizers, conjunctions, determiners, prepositions, pro-forms, and sentence particles (question or imperative markers) (Morgan et al 1996). Based on systematic phonological similarities, Morgan et al identified all the above function words as "minimal" across multiple levels of representation. Function words contain few syllables or moras, have simple onsets and codas, use a more restricted phoneme inventory, have a high token frequency, a high predictability from context, tend to be morphologically simple, and are produced generally with low amplitude and a flat pitch contour, among other similarities (Morgan et al, 1996).

In addition, function words tend to appear at the edges of phonological phrases, which are constructed with reference to syntactic constituents (Gerken 2001; Shady and Gerken 1999; Shafer, Shucard, Shucard, and Gerken 1998, Christophe et al., 1997). If babies can anticipate this consistent location for phrase boundaries and for function words, which consistently provide a cue to immediately adjacent content words, they already have two important tools for drawing conclusions about grammatical category assignment. Similarly, adults could use phrase boundaries to make a generalization about the type of words located at their edges, then about content words within these phrases.

Research on language acquisition has shown a different pattern for function words and content words (e.g., Brown and Hanlon, 1970), with function words typically missing in children’s early production in many languages. As a syntactic natural class, function morphemes are the heads of functional projections, which appear very late in children's speech (Radford 1988). However, the lack of function words in early production does not imply that infants do not represent and process these items. It does provide additional evidence that the function-content word distinction exists at some psychological level even in babies.

Shipley, Smith and Gleitman (1969) first found that children under the age of three responded better to commands containing grammatical function words even though they did not yet produce those words. This led to the hypothesis that children know much more about the functional morphology of language that their production data would lead us to believe. Consequently, finding that very young infants know function words would help us postulate one way they may go about building syntactic categories.

A number of studies found evidence that infants are sensitive to whether function words in language samples they hear are missing, ungrammatical, or foreign. This indicated that infants have identified the grammatical function words of their language, and this was shown for infants of very young ages. Shady (1996) and Shafer, Shucard, Shucard, & Gerken (1998) and Shi, Cutler, and Cruickshank (2005) found this sensitivity for 10-11 month old infants.

Additional studies have sought to explain exactly how children are able to learn function words at such an early age. A number of studies have shown that infants may learn the function words they need to know to form categories based on their perception of prosodic markers such as pauses and of prosodic cues phrase boundaries. Shady, Gerken, & Jusczyk (1995) found that infants are sensitive to the fact that articles, which begin phrases, are in complementary distribution with pauses, which end phrases, because 10-month olds listened longer to passages that contained pauses at the end of a phrase rather than between an article and a noun. They reasoned that learners might use the presence of an article to infer that they are at the beginning of a phrase (Shady, Gerken, & Jusczyk, 1995). Christophe and Dupoux (1996) then noted that since infants are capable of perceiving prosodic phrase boundaries, they might observe that function words often occur at the edges of these phrases and learn these words. Then in turn they could use their knowledge of function words to draw inference about the syntactic relationship of function words with co-occurring content words. To further explain how infants might learn function words based on their prosodic properties, Shi Morgan and Allopenna (1998) reported that a group of concurrently available prosodic and phonological properties reliably distinguish function words from content words across languages as typologically distinct as English, Mandarin, and Turkish.

As studies established that infants can recognize function words in continuous speech and distinguish them from content words, researchers began to test how early infants know that function words only co-occur with some words and not others. Evidence of knowledge of these co-occurrence patterns would suggest that infants might use this knowledge to draw inferences about the syntactic category of words. Gerken and McIntosh (1993) first showed that infants are aware of these co-occurrence patterns. In this study, infants of 23 to 28 months of age performed better on a picture-identification task when the object noun they were asked to identify was preceded by a grammatical article, in contrast to when the object noun was preceded by either an ungrammatical auxiliary or a nonsense word. These results demonstrated that children are sensitive to the co-occurrence relationships of certain function words and experience comprehension difficulty when these relationships are violated. This finding added support to the hypothesis that children could use these patterns from a very early age to form initial category bracketings.

Zangl and Fernald (2005) recently found that sensitivity to ungrammatical function words was available even earlier but varied with age and therefore with linguistic ability: performance on a looking task when function words were missing or ungrammatical was worst in 18 month-olds, less disrupted in 24 month-olds, and undisrupted in 36 month-olds. This suggests first of all, that knowledge of the co-occurrence restrictions of function words is readily available to the youngest infants, but also that as children get older they are able to recruit other strategies to recover from the ungrammaticality and succeed at the task of picture identification. The on-line nature of their incremental looking task also showed that children attend to function words as they unfold in the continuous speech, which supports adult studies that show grammatical processing occurs incrementally.

Additional infant studies show how infants use their knowledge of function words in conjunction with their knowledge of prosody. Shady and Gerken (1999) showed that two-year-olds not only used their knowledge of function words in listening comprehension tasks, they performed significantly better when sentences contained natural prosodic pauses than when pauses fell between a function word like *the* and the following noun. Infants performed best on a listening comprehension task when a prosodic break occurred at the edge of a syntactic constituent, and an appropriate function word appeared at the beginning of that constituent. Shady and Gerken found that these two types of cues were equally beneficial to children's listening—one type of cue did not diminish the usefulness of the other.

Golinkoff, Hirsh-Pasek, and Schweisguth (2001) found results similar to those of Gerken and colleagues, but by examining dependent verbal morphology that did not precede the tested content words. They found that infants watched pictures of events more when listening to sentences containing verbs with grammatical endings like *–ing* than those ending ungrammatically in *–ly* or with nonsense syllable at the end.

Santelmann and Jusczyk (1998) earlier showed that infants attend to discontinuous frames in speech. Another study built on the findings of Santelmann and Jusczyk (1998) on infants' sensitivity to non-adjacent grammatical dependencies. Gouvea, Aldana, Bell, Cody, de Groat, Johnson, McCabe, Zimmerman, Kim (2005) conducted a headturn preference experiment designed to test whether 15- to 18-month-olds are able to use their knowledge of a certain type of functional morphology, number agreement between determiners and nouns, marked in English by a null ending or the plural *–s* ending on the noun, to distinguish grammatical from ungrammatical usages of the morphology. The authors found evidence that 18 month-olds, but not 15-month-olds, listened longer to passages containing grammatical dependencies of correct number agreement between determiners and nouns.

Other studies have provided evidence that infants can actually generalize new categories based on artificial or unfamiliar natural language inputs, rather than just demonstrating sensitivity to category differences. This provides an analogy for how infants might perform this operation with the input from their native language. Gomez and Lakusta (2004) provided a valuable example of this by showing that 12-month-old infants categorized novel words in an artificial language based on their co-occurrence with marker items during familiarization. In a study that was similar, but which used natural language data as stimuli, Gerken, Wilson, and Lewis (2003) familiarized monolingual English-speaking 17-month-old infants to a Russian gender paradigm, from which they withheld a subset of items. During test trials, infants heard either items from the withheld subset of the gender paradigm as well as ungrammatical items in which previously heard stems were inflected with markings corresponding to a different grammatical gender. The results showed that infants were able to discriminate grammatical items from ungrammatical items, none of which they had previously heard, after being familiarized to the gender paradigm for about 2 minutes. However, they were only able to perform this discrimination when items were double-marked for grammatical gender. The authors concluded that infants can quickly form categories purely by observing co-occurrence patterns in a data from a real human language, without having reference to the meanings of the either word stems or the inflectional morphology.

In summary, infant studies show that by the age of 2, babies are aware of a list of function words that regularly precede either nouns or verbs, and can distinguish them from words that do not regularly co-occur in one of these patterns. This knowledge, in combination with the ability to exploit the other types of regularities discussed here, provide infants with tools for developing syntactic categories.

Before continuing, I will review the aspect of the model of grammatical category acquisition developed here that is relevant to this dissertation. Many studies have shown that infants can recognize function words well before they are able to produce them. Saying that infants recognize function words is the same as saying they have begun to notice them and compile them into an inventory of learned elements, noting the similarities between them and deciding to group them as one general class. Or, at the time infants begin to recognize function words they simultaneously notice co-occurrence patterns with certain content words, and then build on this to generalize the types of content words that occur with a particular function word. On this logic, knowing the function words of their language could help infants both to recognize content words that co-occur with them, group these content words into classes, and label these classes as the appropriate grammatical category of their language.

A further question that linguistic theory has been interested in is whether these grammatical categories are basically innate in infants (Chomsky 1965), requiring only to be filled in through the use of the most reliable information, or whether infants can actually induce grammatical categories just by performing distributional computations on the input (e.g. Maratsos and Chalkley, 1980). Regardless of this distinction, the research I have reviewed here helps establish simply what perceptible information in the signal correlates with grammatical category distinctions, meaning that this information could be reliably used to complete infants' representations of grammatical categories on either type of theory.

1.2.2.3.1. The function-content distinction beyond the domain of acquisition theory

The function-content word distinction has been recognized and incorporated in virtually every major area of language research, including parsing, production, and neurolinguistic studies of language disorders.

Behavioral studies concerned with lexical access have found asymmetries in the processing of function words vs. content words. Bradley (1978) reported that lexical decision reaction time to content words was dependent on individual word frequency, while reaction times to function words was not. The difference in sensitivity to frequency was first taken to support the notion of separate lexical access routes for the two classes, and a model of privileged access to function words (also Bradley, Garrett, and Zurif 1980). Though further studies (Gordon and Caramazza 1982) failed to find the same relationship between frequency and speed of lexical access in both function words and content words, both Gordon and Caramazza (1982) and Bradley (1978) upheld the basic finding of overall differential lexical decision times to function words versus content words, despite different conclusions on the influence of word frequency.

More recently, Segalowitz and Lane (2000) conducted a reading-time study with normal adults that found shorter reaction times to function words than to content words, but also still agreed with Gordon & Caramazza's (1982) claim that there is a confound between word class and frequency, and that frequency and predictability (as measured by cloze probability in their study) account for the lexical access timing properties that differentiate function and content word classes.

A number of additional studies have given evidence for various types of processing differences distinguishing content words from function words. A study reported by Friederici (1985) used a word-monitoring task to find differences in reaction times to the two classes of words. Other studies have demonstrated that adults often miss errors involving function words while performing proofreading tasks (Rosenberg, Zurif, Brownell, Garrett, & Bradley, 1985); and a recent study showed that phonological processes of deletion or assimilation are more likely to occur with function words than content words (Shi, Gick, Kanwischer, & Wilson 2005). To summarize, these studies provide evidence from an area outside of acquisition research that function words and content words are processed differently. This can in turn be interpreted as additional support for the idea that a learner may treat these broad classes differently during acquisition, with the functional classes helping to bootstrap the content class.

Research on neurolinguistic theory has often considered the question of whether function words are represented in the brain as different from content words. Support for differing representations has been taken from studies on the function-content word distinction in lexical access using event-related potential (ERP) measures as well as various behavioral and imaging studies conducted with aphasics and unimpaired subjects. ERPs give a temporal analysis of a response to an event and also reflect the localization of a response in the cerebral cortex to some extent. Neville, Mills, and Lawson (1992) conducted an ERP study in which they found a significant difference between content and function words in early frontal ERPs, as well as a significant difference in localization patterns of responses to the two word classes at a later stage. Another ERP study using a lexical decision task found that function words produced a large negative peak over the left hemisphere, while content words did not show any response lateralization (Pulvermuller, Lutzenberger, & Birbaumer, 1995). Pulvermuller (1999) showed evidence that lexical access for function words involves the perisylvian region while lexical access for content words involves this region plus other cortical areas related to the meanings of the words.

Aphasiology studies have reported evidence to suggest that the use of function words is dependent on structures in the anterior regions of the brain compared to content words, meaning that certain forms of damage can result in a relative loss of use of function words compared to content words (Bradley, Garrett, & Zurif, 1980). In an event-related fMRI study conducted with unimpaired subjects, Friederici (2000) found different patterns of cortical activation to function words versus content words when subjects were asked to categorize visually presented words as either nouns or function words. Discovering the potential neurological bases of function word classes and content word classes is one way to explore how humans might be innately wired to process these word classes differently and therefore, may do so from the earliest stages of language acquisition.

Comprehension models such as that proposed by Townsend and Bever (2001) take such evidence as support for an early strategy that builds a framework of function words and morphemes before complete syntactic structure is assigned in a subsequent process. The content-function distinction also strongly affects learnability; for adult English speakers, an artificial language grammar is not learnable without functional markers of grammatical structure (Green, 1979). Cutler (1993) showed that an artificial learning simulation was performed better when content-like elements were realized with full vowels and other acoustic markers characteristic of content words, as well as when functional elements were also acoustically realized with reduced vowels.

Theories of production (Levelt 1989; Levelt, Roelofs, and Meyer (1999) treat function words as a distinct vocabulary with elaborate lemma representations and scant lexical-conceptual content, the inverse of content words; function words with particularly low semantic content are accessed for production through a completely different procedure than content words. In summary, most models of language comprehension and production assume that lexical-semantic processes and syntactic structure-building processes are distinct; these processes roughly map onto the distinction between function words and content words. Empirical studies with both normal and impaired subjects have provided support for the view that functional elements and content-bearing elements are represented, stored, and processed differently. Finally, the evidence that adults (and computer simulations) learn, process and suffer comprehension impairment to these classes differentially suggests that language learners may be predisposed to treat these broad classes as distinct during acquisition. Infants' recognition of this distinction could then be a preliminary step to using of function words to bootstrap grammatical categories for the content words they know .

1.2.3 Bootstrapping theories of language acquisition

Having looked at the tasks required for infants to be able to segment and label words from the speech stream, it is worthwhile discussing how these tasks fit into hypotheses of the acquisition of a grammar. A circularity known as a bootstrapping problem (Pinker 1987) concerns whether infants need to know word meanings first before using them to learn about syntactic structure, or whether syntactic structure can be partially constructed by noticing certain distributional regularities, then used to learn the meanings of words.

1.2.3.1. Semantic bootstrapping vs. syntactic bootstrapping

Several types of theories have addressed the question of grammatical category acquisition in children. The semantic bootstrapping hypothesis is the claim that infants first need to acquire the meanings of some words (verbs) in order to infer their subcategorization frames (Grimshaw 1981, Macnamara 1982, Pinker 1984). On this theory, infants are born with conceptual structure that leads them to expect to find a set of grammatical categories in their language input. They are also born knowing how to link words that they encounter in their input to these innate conceptual categories. For example, they learn from their earliest input that nouns typically denote objects, verbs denote actions and events, and adjectives denote properties. The infant then uses these conceptual linking rules to map words onto the innate grammatical categories, using the prototypical semantic properties as a guide. Once these categories are filled in with sufficient mappings of words to semantic concepts, infants then shift their attention to structural correlates of the words they have already categorized via semantics, building up the categories further by observation of distributional patterns. On this hypothesis, semantic linking is the initial bootstrap into grammatical categories, which later cedes to the infant's ability to make use of distributional patterns. The learner uses "canonical structure realization rules" (Pinker 1984) to infer a mapping from meaning to grammatical category, even if the categories themselves are not organized based on semantic similarity.

An important question to ask about this hypothesis is why, if distributional properties can be used to assign words to categories, do learners not make use of them right from the start? One argument for the semantic bootstrapping hypothesis was that some of the most reliable markers of syntactic categories, function words, are not present in very young children's vocabularies. Since then, a great deal of evidence has been amassed to build on Shipley, Smith & Gleitman's (1969) finding that infants have knowledge about function words even though they do not yet produce them (Gerken & McIntosh 1993, Shafer, Shucard, Shucard, & Gerken 1998, Höhle & Weissenborn 1999, Shi, Werker & Morgan 1999). The other argument that syntactic categorization should start with semantic reference comes from the idea that grammatical categories are substantive universals (Chomsky 1965). On this approach, the only way to link the innate categories to distributional information from the input would be by means of the semantic linking discussed above (McNamara 1981, Grimshaw 1981, Pinker 1984).

Conversely, distributional approaches (Maratsos and Chalkley 1980, Cartwright and Brent 1997) argue that learners can build categories without an innately specified semantic core based on distributional information in the input. In this vein, the syntactic bootstrapping hypothesis claims that children learn structural relations like verb subcategorization frames first, then use them to restrict their hypotheses about possible word meanings (Gleitman and Wanner 1982, Landau and Gleitman 1985). The idea behind this approach is that knowing detailed information about the categories of the syntactic constituents helps learners begin to acquire semantic information about the words. Recent studies suggest that speech input to children contains distributional regularities that reliably correlate with some grammatical categories, such as nouns and verbs (Mintz, Newport, & Bever, 2002), and that the learner may be able to derive these categories based on such regularities.

However, both semantic and syntactic bootstrapping depend on children's ability to learn the subcategorization frames of some words without knowing their meanings (Brent 1994). Problematically for semantic bootstrapping, cross-linguistic variation results in different subcategorization frames corresponding to different meanings depending on the language being learned. Therefore, children would have to learn a language-specific correspondence between meaning and subcategorization before choosing the right subcategorization frames for the words they know. In order to get to that point, children would have had to learn some subcategorizations independently of their meanings. As an exception, Lidz (2006) proposes that children can begin to acquire semantic meaning independently of syntax thanks to broad linguistic generalizations that do not rely on detailed language-specific mappings, for instance, that propositions are realized as clauses. This allows learners to begin acquiring large-scale semantic categories without knowing the full range of syntactic distinctions of their native language. Furthermore, Lidz (2006) cites the universal mapping between the semantics of verb causation (the participants involved) and syntactic transitivity (the argument structure encoded by a transitive verb) as a way that learners could easily get from verb syntax to verb meaning without being limited by language-specific syntactic distinctions. A series of studies with English and Kannada-speaking children showed that, in sentence act-out tasks, children's decisions about verb meaning were guided by their inherent expectations about the syntax-semantics mapping rather than by morphosyntactic cues marked reliably in the input. This illustrates a way in which learners could solve the circularity problem, learning about verb frames from structural evidence but mapping directly to meaning in cases where languages make this mapping universally reliable.

To summarize, the main problem of acquisition for children is to find a way to learn some things about syntactic structure, independently of meaning. The research reviewed here supports a proposal known as the prosodic bootstrapping hypothesis, which holds that children can recover some syntactic information from prosodic and distributional information.

1.2.3.2. How to bootstrap syntax from the speech signal

Stemming from the syntactic side of the bootstrapping question, prosodic bootstrapping is the hypothesis that young children use prosodic information to infer syntactic structure, potentially an unlabeled bracketing of all major syntactic constituents (Gleitman and Wanner 1982, Morgan 1996). In order to support this hypothesis, it is necessary to show that young children attend to prosody and that some syntactic structure can be recovered from the prosodic information of sentences. Indeed, many studies have established infants' ability to perceive the correspondence between prosodic and syntactic boundaries, using both preferential looking and non-nutritive sucking paradigms to determine that babies prefer stimuli in which prosodic properties like pauses, pitch changes, and lengthening coincide with syntactic boundaries (Jusczyk and Kemler-Nelson 1996). Before reviewing evidence from infants studies to support the model of prosodic bootstrapping, I will first discuss theories of the phonology-syntax interface which describe the prosodic domains which have been thought to constrain infants' learning of syntactic structures.

1.2.3.2.1 Some theories of the phonology-syntax interface

Prosodic phonology (Selkirk 1984; Nespor and Vogel 1986) proposes several layers of prosodic representation between the utterance level and the word level, in which constituents such as intonational phrase, phonological phrase, and clitic group are ranked and layered. (Figure 1).

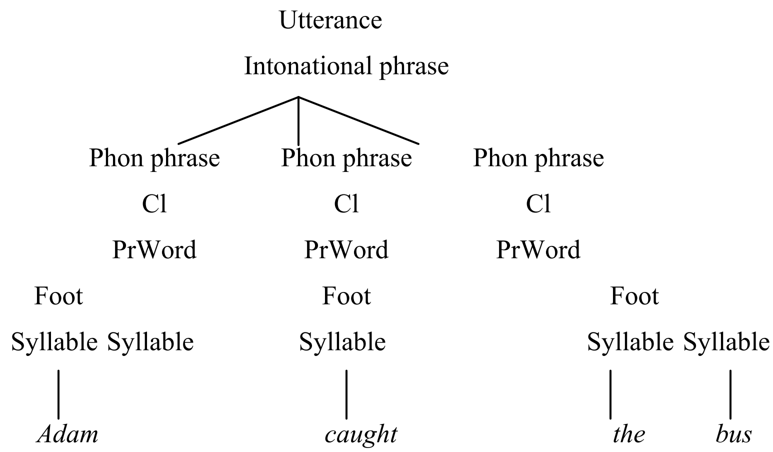

Figure 1: The levels of the prosodic representation mediating syntax and phonology, based on Nespor and Vogel (1986)

On this model, the prosodic representation is generated by a set of rules or constraints from a syntactic representation. This level of representation was proposed in part to account for the observation that the boundaries of syntactic phrases do not always line up with the boundaries of phrases over which phonological and prosodic rules apply. A notable example was given by Chomsky and Halle (1968):

syntactic phrasing

3) This is [the cat that caught [the rat that [stole [the cheese]]]

prosodic phrasing

4) (This is the cat) (that caught the rat) (that stole the cheese)

The theoretical machinery of Prosodic Phonology operates on the premise that phonological rules cannot refer directly to syntactic structure, but refer to prosodic constituents like phonological phrases, allowing an intermediate level of derivation between syntax and phonology. On this model, mismatches like (3) and (4) due to non-isomorphism between the hierarchical structures of phonology and the hierarchical structures of syntax, are accounted for if the prosodic phrasing rules in (4) apply over an intermediate representation derived from (3).

For a learner of a language to be able to bootstrap syntactic structure from prosodic information, the issues outlined above means that finding the boundary of a prosodic unit is a good cue to the presence of some syntactic boundaries, but not others. The problem lies in the fact that hierarchical levels of syntactic structure may be contained within the prosodic unit without the benefit of perceptible prosodic marking. Gerken (2001) notes that the lack of isomorphism between prosodic units and syntactic units probably does not prevent listeners from using prosody effectively to find some syntactic boundaries, but that it would lead to undersegmentation of the input if prosodic cues were used alone.

Of the prosodic representation units proposed by Prosodic Phonology, the phonological phrase in particular is often implicated in segmentation strategies because of its frequent correspondence to lexical subject and predicate phrases. However, it, like other prosodic units, is not a perfect predictor of syntactic phrase boundaries. This is observed in the case of sentences headed by pronoun subjects: sentential subjects like *he* tend to form a single prosodic unit with the following predicate.

Seidl (2001) modifies these theories of the prosody-syntax interface by allowing that syntax can make direct reference to phonology without the intermediation of phonological phrases, but in a limited way. Seidl's theory consists of two levels, one in which phonological rules are conditioned directly by morphosyntactic information and a second in which rules which apply to intermediate domains constructed from the syntax. Seidl's version of this intermediate level is extremely restricted compared to that of Prosodic Phonology: on her model, prosodic phrases only differ from syntactic phrases in whether they are mapped onto the right or left edge of a syntactic domain where theta-roles are assigned.

Providing data from languages like Yoruba, German, and Chichewa, Seidl (2001) proposes a two-phase, two parse model in which early rules apply to a morphosyntactic representation and late rules apply to a phonological representation. Theoretically, this model's creation of a distinction between two phases and domains of phonological rule application allows for the subtraction of the intermediate level of representation needed in Prosodic Phonology. On Seidl's account, the prosodic hierarchy is unnecessary because her theory provides a way for a very limited amount of syntax to be directly visible to phonological structure, just the theta-role information that is output from a morphosyntactic derivation and is also available to semantic representation.

One consequence that such an account of the prosody-syntax interface has for models of acquisition is that the process of bootstrapping is made simpler if infants can acquire crucial parts of their grammar directly from phonological information. Seidl's account is also desirable for a cross-linguistic model of prosodic bootstrapping because language-specific constraints on prosodic boundary cues are not required; phonological domains fall out directly from the syntactic structure of each language.

To summarize, the lack of isomorphy between syntactic and phonological structure is at the root of the development of theories of indirect reference (Seidl 2001), in which some or all of syntactic structure is invisible to phonological rules. As a solution, these theories have proposed some type of process that mediates between syntax and phonology. These theories bear directly on the model of prosodic bootstrapping, because this acquisition model depends on some reliable mapping between phonology and syntax that learners can start to build into their grammar via information that comes directly from the speech signal.

1.2.3.2.2 The prosodic bootstrapping hypothesis

Prosodic bootstrapping (Gleitman and Wanner 1982) proposes that infants can take information directly from the acoustic signal of speech and use it as a way to learn syntactic phrase structure without first having to know all of the words (and their meanings) that need to be incorporated into this structure. Of course, prosodic bootstrapping, like other bootstrapping models, contains a circularity problem: the phonotactic constraints and lexical statistics discussed in the previous section are highly language-specific, so infants might need to know a lot about the words of a language before being able to generalize such useful cues to word boundaries (Christophe and Dupoux 1996). Cross-linguistically available types of sound-related information, such as pauses, have been proposed as bootstraps into this problem. The variety of sources of prosodic information in the input as well as the reliable perceptibility of this information indicates that this type of bootstrapping is indeed possible (de Pijper and Sanderman 1994). Specifically, Christophe and Dupoux (1996) propose that the boundaries of prosodic constituents can be located using cross-linguistically available prosodic information such as duration, energy, and pitch. These prosodic boundaries are marked out in a first-pass segmentation of the input, then used to acquire language-specific information related to segmentation, such as phonotactic constraints.

The following studies report evidence that infants are sensitive to such prosodic units, which on one model of processing exist at a pre-lexical level of representation and mediate between the acoustic input and lexical processes (Christophe et al, 1997). Sensitivity to prosodic units was first tested in experiments in which infants were presented with phrases marked by normal prosody and phrases marked by disrupted or abnormal prosody, which showed that infants can recognize such a difference. Jusczyk, Hirsh-Pasek, Kemler-Nelson, Kennedy, Woodward, and Piwoz (1992) found that nine-month-olds respond faster when hearing sentences in which pauses coincided with syntactic phrase boundaries than when pauses fell within phrases. Gerken, Jusczyk, and Mandel (1994) found that nine-month-olds listened longer to sentences in which pauses were inserted between prosodic boundaries rather than within them, even when those prosodic boundaries do *not* coincide with a syntactic phrase boundary, suggesting that babies might use prosodic units to constrain their learning about syntactic constituency.

Christophe, Dupoux, Bertoncini, and Mehler (1994) found that 3-day-old newborns can discriminate lists of bisyllabic strings depending on whether they were spliced from inside a word (*mati* from *mathematicien*) or across a phonological phrase (and word) boundary (*mati* from *panorama typique*). Christophe, Nespor, Guasti, and Van Ooyen (2003) found that infants can discriminate carefully matched samples of two languages, Turkish and French, when the samples were filtered to remove all language-specific information other than the prosodic markers of phrasal stress, which corresponded reliably to the head-direction of phrases in each language (head-initial in French, head-final in Turkish). The authors concluded that because newborns could discriminate the samples and thus perceive the prosodic correlates of phrase prominence, they could use this information immediately to determine the syntactic parameter of head direction in their native language.

In summary, the above studies show that infants are able to perceive and use prosodic information to enrich their representations of language input. In order to draw parallels between infant language acquisition and adult lexical access and enrich models of both processes, we assume that prosodic and distributional information that is robust enough to be perceived and exploited by babies should be equally available to adults. Conversely, information that adults exploit regularly should be examined for its usefulness to learners as well. Although adults may have developed more efficient strategies that make some acquisition strategies obsolete, a sound assumption is that if robust regularities exist in the signal, they will be used to some extent in perception by both children and adults.

1.3. The current study

This dissertation develops a hypothesis of function word predictiveness, which holds that the rapid identification of function words enables listeners to make predictions about the grammatical categories of upcoming words, speeding up access only to words that are strongly predicted to follow. Many distributional, phonological and prosodic properties that make function words useful for acquiring syntactic categories have already been identified as reviewed here; the purpose of this work is to create a clearer picture of how adults and children exploit these properties in combination with prosodic boundaries to create an initial parse of language input that includes syntactic category labels.

This dissertation explores children's ability to perform such a syntactic analysis in order to categorize novel words in two preferential-looking experiments, and compares the findings to adults' performance in two experiments requiring on-line lexical access modulated by the grammaticality of a preceding function word. The evidence from these experiments shows that one particular piece of the information used by adults to anticipate syntactic structure in the incoming speech stream is also used by infants to discover syntactic structure. This finding leads to a further important conclusion, that a robust source of predictive information available in the signal is used for different types of analyses by listeners and learners.

The experiments described here take as a starting point the recent body of evidence reported by Christophe and colleagues (1996, 1997, 2001, 2003, in press). Christophe et al (1997) showed that French-speaking adults reacted to phoneme targets faster at the boundary of a content word directly after a determiner, than they did when asked to find this phoneme at the boundary of a content word following another content word. On the model of lexical access they propose, the first representation available to the human language parsing mechanism is bracketed by prosodic phrase boundaries and has the function words filled in at the phrase edges. They concluded that the results of the adult phoneme-monitoring experiments supports a hypothesis of function-word stripping, in which listeners strip off the function words provided in the pre-lexical representation to quickly access content words following function words.

However, it remains an open question whether function words provide a cue to following word boundaries alone, or whether the rapid identification of function words enables the processor to quickly predict the category of the next word. In Experiments 1 and 2, we evaluate whether function words also help construct a fast syntactic parse, giving the listener information about the category of the word that will follow. The effect of the proximity of a prosodic boundary to a function-content word co-occurrence is also examined. Experiments 3 and 4 are designed to test children's syntactic processing using function words and compare it to that of adults. By extending the findings of Experiments 1 and 2 to infants, the significance of the previous findings on the interplay of function words and phrase boundaries in lexical access will be broadened to include information on their role in language acquisition.

1.4. Summary

The goal of this research program is to more precisely link the process of function word identification and the process of syntactic category assignment in both acquisition and adult comprehension. The significance of function words as a cue to word boundaries and their utility as predictors of following word categories have long been established; this work draws a link between these two properties and evaluates the interaction of prosodic and syntactic knowledge in word acquisition and recognition.

In addition to generating results that contribute to current models of sentence processing, this dissertation contributes to our understanding of the mechanisms of grammatical category acquisition. Language acquisition is the subject of intense focus today both because of the advancements in techniques used to study a child's knowledge, and because it strikes at one of the most elemental goals of the field of linguistics. In effect, discovering how we learn language is the same as discovering what language is, and how our brain produces this unique human behavior.

The articulation of this aim, for the modern era of cognitive science, dates to when Chomsky (1965) made first language acquisition the criterion against which to evaluate the explanatory adequacy of a theory of linguistics. Chomsky defined the task of the linguist as the same as the task for a child learning a language: to determine a set of underlying principles that are what is known by a person who knows this language. A generative grammar is defined as "a restrictive and rich hypothesis concerning the universal properties that determine the form of language" (p.38), by which is meant both what results from a child's inborn capacity to account for the linguistic data in the environment, and the general principles which underlie the language of a particular community. A generative grammar is intrinsically linked to a theory of acquisition: when applied to primary linguistic data, the right acquisition theory generates an adequately explanatory grammar of any human language. The current study and other studies reviewed here strive to develop some of the details of an acquisition theory that could satisfy this requirement.

This dissertation will be organized as follows. Chapter 2 details the design, implementation, and results of Experiments 1 and 2, asked whether function words can help adult listeners make strong on-line predictions about syntactic categories in a way that speeds lexical access. Participants in these experiments performed a word-monitoring task, viewing word targets on a computer screen and listening to sentences via headphones, pressing a button when they heard the desired target. The sentence contexts and the critical items differed along a number of dimensions, including the size of a prosodic boundary preceding the target word, the category of the target word (noun or verb), the grammaticality of the target (whether an auxiliary verb was followed by a verb or by a noun, for instance), and the measure of frequency on which the target nouns and verbs were matched to each other (wordform or lemma frequency). The results show that adults identified targets faster in grammatical contexts, suggesting that a preceding function word helps the listener construct a syntactic parse that affects the speed of word identification. Also, a larger preceding prosodic break facilitated target access more than a smaller break. As background to this, a set of adult phoneme-monitoring experiments which informed the construction of materials for Experiments 1 and 2 are described. Experiments A and B were modeled on Christophe et al's 1997 study from which they developed the hypothesis of function word stripping. In these experiments, we found that adults reacted faster to phoneme targets on nouns following determiners than on adjectives following determiners, but this effect interacted with sentential position. To achieve a better design, these experiments were recast with a word-spotting task in Experiments 1 and 2.

Chapter 3 describes Experiments 4 and 5, which adapt the task demands of Experiments 1 and 2 to an infant head-turn preference procedure, examining how 15-month olds use determiners and auxiliaries to categorize novel words. In Experiment 4, infants were familiarized to phrases consisting of a real function word (a determiner or an auxiliary) paired with a novel monosyllabic word. They then heard sentences in which the familiarized nonsense words were used in a syntactic context appropriate to a noun or verb, preceded by a different function word than the one used during familiarization. The results showed that infants listen longer to sentences in which the novel word occurs with a function word from the same category used during familiarization. In Experiment 5, infants were familiarized to passages containing test sentences from the previous task. In test trials, they heard an appropriate or inappropriate functor paired with the familiarized pseudowords, as well as an unfamiliar distractor word. The results showed that infants listen longer to novel words when paired with a functor of the familiarized syntactic category, suggesting that, like adults, infants recognized words targets better when they matched their syntactic expectations. Other recent studies that also explore infants' ability to categorize novel words are discussed in the context of these findings.

Chapter 4, the conclusion chapter, summarizes the results of each of the experiments, discusses larger implications of the results, and proposes future avenues of research. This includes a discussion of how Experiments 1 through 5 demonstrate that certain reliable information at the prosody-syntax interface is exploited in both lexical acquisition and adult lexical access. Taken together, the experimental evidence presented in this dissertation underscores that information used by adults to predict syntactic structure on-line is also used by infants to build grammatical categories. This supports the idea that a theory of acquisition should prominently feature knowledge of function word co-occurrence patterns as a bootstrap into grammatical categories.

CHAPTER 2

The experiments reported in this chapter investigate the roles of grammatical form classes and prosodic boundary information in adult sentence processing. In this program of research, I investigate whether their role is only to facilitate fast lexical access, or whether they also help construct an initial syntactic parse.

As discussed in Chapter 1, function words can be distinguished from content words by a variety of phonological, statistical, and acoustic properties. These properties may help listeners quickly identify function words in the speech signal. Christophe, Guasti, Nespor, Dupoux, and Van Ooyen (1997) showed evidence that the rapid identification of function words allows listeners to posit a word boundary, facilitating identification of the onset of the following word, and speeding lexical access for that word. This process of function-word stripping thus speeds lexical access, while the distributional co-occurrence properties of function words can help listeners generate predictions about the category of the following content word.

As discussed in Chapter 1, infants are also able to recognize the prosodic features that distinguish function words from content words (Gerken and McIntosh 1993), so they may also use this knowledge to access to a content word that immediately follows.

Christophe et al (1997) demonstrated that French-speaking adults use function word stripping to quickly access nouns following determiners. However, it remains an open question whether function words provide a cue to following word boundaries alone, or whether the rapid identification of function words enables the processor to predict the category of the next word. That is, does function-word stripping play a role only in the process of segmentation or does it also contribute to syntactic parsing? In this research program, we evaluate the following hypotheses:

(1) Function words only facilitate fast lexical access, telling the listener that a new content word is about to begin

(2) Function words help construct a fast syntactic parse, giving the listener information about the category of the word that will follow.

In this dissertation, (1) will be referred to as the *function-word stripping hypothesis,* based on Christophe et al's (1997) proposal. Hypothesis (2) will be referred to as the *function-word predictiveness* hypothesis. The experiments presented in this chapter are designed to test the function word predictiveness hypothesis.

The experiments reported here also examine the effect of the proximity of a prosodic boundary to a function-content word co-occurrence. On the function-word stripping hypothesis developed by Christophe at al, identification of a prosodic phrase boundary facilitates rapid identification of a function word at its edge. We predict that if a larger prosodic break leads to quicker identification of a prosodic phrase boundary, targets will be recognized faster after a large prosodic break than after a small one. In addition, the experiments reported here allow us to test whether a prosodic break and the predictive properties of function words work additively together to speed access to a following content word.

The following diagram summarizes the model of word recognition proposed by Christophe et al (1997) (Figure 2):

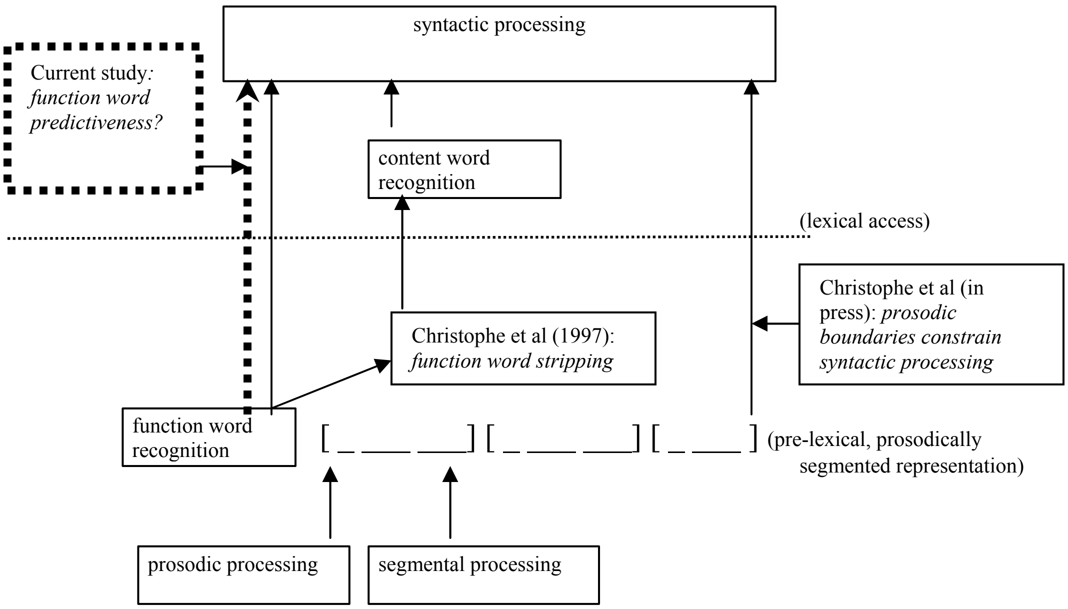

Figure 2: A speech recognition model, adapted from Christophe et al., (1997, in press)

The above model illustrates Christophe et al. (1997)'s claim that function-word stripping facilitates recognition of a following content word, as well as the current hypothesis that function words strongly predict the grammatical category of an upcoming content word.

The results of the experiments presented in this chapter show that the grammaticality of a preceding function word significantly affects the speed of lexical access to a following word, supporting our hypothesis of the syntactic predictiveness of function words. Furthermore, the speed of target identification is facilitated more by a larger preceding prosodic boundary than a smaller one. In addition, the effects of word frequency on the speed of target identification in these experiments are consistent with the literature on this topic, indicating that normal lexical access processes are at work.

2.1 Prior Experiments

Christophe et al (1997) conducted an experiment in which adult subjects searched for word-initial target phonemes that fell at the boundary between a function word and a content word or between two content words. They varied the phoneme-finding task for their two subject groups: one group was instructed to find the target phoneme wherever it occurred in the sentence; the other group was asked to respond to the target only if it occurred at the beginning of a word. The results revealed a significant interaction between task and target position: when the target was on the noun, immediately following the determiner, subjects were equally fast at both tasks. But, when the target was on the adjective, following the noun, subjects were slower to perform the word-initial task than the generalized task. The authors concluded two things: that a word boundary following a function word is more readily available, and that the fact that reaction times were unaffected by the task requirement precisely at this location means that phoneme detection is available pre-lexically.

Their finding that reaction times were faster for target phonemes between a function and a content word led them to hypothesize that a first prosodic organization of the input is filled in with function words, which are quickly recognized at the boundary edges of this first-pass segmentation. A process of “function-word stripping” produces fast access to a following content word and speeded recognition of a target phoneme located in it.

However, the fixed relationship of the syntactic constituents of the noun phrase in Christophe et al’s experiment meant that the function word always preceded a noun in their stimuli, and the noun always preceded an adjective. Since the word-order requirements of English reverse the position of adjective and noun, we can ask whether the advantage for a content word following a function word would hold in a similar experiment with English noun phrases. The difference between these effects is illustrated in (1) and (2), using a sample noun phrase from the original experiment in French.

5) un fou larmoyant
[Det____N ____ Adj]
i. /x/ /x/
ii. RT1 < RT2

French noun phrase like that used in Christophe et al (1997)

6) a sad fool
a. [Det____Adj ____ N]
i. /x/ /x/
ii. RT1 ? RT2

English noun phrase like those used in the Experiment A

The following pair of experiments were designed to investigate whether rapid function word identification contributes only to lexical processing or also contributes to syntactic processing. However, other possible outcomes included the possibility that these processing advantages are additive, resulting in fast reaction times to both adjectives and nouns; that no processing advantages appear in this environment in English as they do in French; or that the same cues that were effective in French are effective in English, resulting in a replication of the function-word stripping effect.

In addition to the contrast furnished by the head-modifier order of English (mod-N) vs. French noun (N-mod) phrases, these experiments differed from the model in another important way. The placement of the noun phrases within Christophe et al's stimuli sentences was counterbalanced between the beginning, middle, and end of "rather long sentences." In their results, they found no main effect for the position of these phrases within the sentences and no interaction of this sentence position with any other factors.

However, the importance of the location of a prosodic boundary to the function-word stripping hypothesis suggests the need to control the location of the target with respect to other prosodic units in test sentences. To address this issue, the noun phrases in this experiment were placed at a point in the sentence that coincided with another predictable prosodic boundary. The target noun phrase was sentence-initial in half of the test sentences, and in the other half was placed medially as the sole obligatory object of a transitive verb, the main verb of the sentence. In addition, the number of syllables and the stress pattern preceding the target noun phrase were matched for the sentence-medial position. The rationale behind the placement of the noun phrases in sentences was to create reliable locations where the phonological phrase boundary would coincide with a larger prosodic boundary (sentence-initial) and where it would most likely not coincide with another boundary, VP-internally (Selkirk 1984). In this way, the subjects' perception of the NP boundaries might be heightened by an additive effect of coinciding boundaries (de Pijper and Sanderman 1994) or conversely, neutralized by distancing from the nearest larger prosodic phrasal unit. In summary, targets were controlled for location with respect to a prosodic boundary.

2.1.1 Experiment A: Det Adj N vs. Det Adj N

2.1.1.1 Method

Twenty-four experimental sentences contained a word-initial target in a noun phrase of the form “determiner-adjective-noun” (the default ordering in English). As in the Christophe (1997) experiment, the position of this noun phrase was varied within the sentence, but appeared only sentence-initially or as the sole complement of the first VP in the sentence. In half of the sentences, the target occurred at the beginning of the adjective, just after the determiner (/f/ “a **f**ast bird”), and for the other half the target occurred at the beginning of the noun, just after the adjective (/g/, “the sick **g**uard”). Twenty-four filler sentences of similar structure and length contained either a word-medial target, a target somewhere outside a noun phrase, or a target not contained in the sentence.

All sentences were read by a female native English speaker who read naturally at a normal to fast rate of speech, instructed to avoid making any unscripted sentence-internal prosodic breaks. The stimuli were recorded at a sampling rate of 22.050 kHz. The sentences were acoustically analyzed to verify that the lack of prominent boundary tones prior to the NP containing the target phoneme indicates the absence of an intonational phrase break between the initiation of the sentence and the word containing the target (Beckman 1996, Shattuck-Hufnagel and Turk 1996, Beckman and Pierrehumbert 1986). The object of this style of reading was to minimize any cue to the listener to infer an intonational or phonological phrase boundary before the target noun phrase, a boundary which should encourage speakers to expect a function word. This reading was chosen as the simplest way to keep the prosodic contours at this juncture consistent across stimuli.

Two versions of the experimental list were constructed to vary the presentation order of the test sentences. The constraints on the experimental list construction were that no target could be repeated over two successive trials, and that there were never more than five sentences in a row that contained the same target.

The stimuli, consisting of the target noun phrases and the sentences containing them, were controlled according to the following criteria.

<u>Constraints on internal composition of the noun phrases</u>

There were 24 test sentences containing subject or object noun phrases of the form [Det Adj N]. 12 of these sentenced contained the phoneme target in the adjective, the other 12 carried the target phoneme in the adjective. All target phonemes occurred word-initially. All 24 noun phrases in the test sentences contained unique components, with the 48 content words used only once each to avoid any priming effect. The 48 content words used in the test sentences were selected from the Kucera & Francis (1967) corpus via the MRC Database, maintained by the University of Washington. Each of these content words was monosyllabic and had a frequency in the range of 20 to 85 (the smallest range within which a group of semantically compatible words with the desired initial phonemes could be collected). The target phonemes were /f/, /b/, /t/, /s/, /n/, or /g/ (attempting to cover a range of articulatory features), and there were exactly four nouns and four adjectives beginning with each of these phonemes. All of the target phonemes for the test sentences appeared word-initially. Target phonemes were also chosen to be visually consistent with the orthography to avoid confusion during the visual presentation and initial consonant clusters were dispreferred whenever possible. The determiners were balanced between *a, the, his*, and *her.*

Constraints on test sentences and trials

In the 24 test sentences, the target phoneme in the noun phrase did not occur anywhere else in the sentence. Within a trial, no target phoneme could be repeated within three consecutive items. 24 filler sentences contained noun phrases of a similar form to the test sentences. In these fillers, target phonemes were located word initially but outside the noun phrase, word-medially within the noun phrase, or did not appear at all in the sentence. Two different, inverse versions of the trial order were made and half the subjects tested on each to avoid order effects.

Position of noun phrase within the sentence

As described above, the possible effect of subjects' perception of a prosodic boundary on the expected function-word stripping was considered. Sentential position of the target noun phrase was either sentence-initial or VP-internal. The syllable length of sentences and stress pattern of sentences preceding the target noun phrase was matched.

Sample Stimuli

Adjective-initial
1. [The **f**aint noise] indicated that the radio batteries weren't dead yet.

Adjective-medial
2. Ronnie needed [a **f**ast bird] in order to win the school's Pet Olympics.

Noun-initial
3. [The faint **n**oise] indicated that the radio batteries weren't dead yet.

Adjective-medial
4. Ronnie needed [a fast **b**ird] in order to win the school's Pet Olympics.

Table 1: Experiment A sample stimuli

Subjects were tested individually or in groups of two in a soundproof room. The subjects received oral instructions that they would participate in a short listening task. Before each sentence, a letter would be displayed in the center of the screen, which was the target to be detected. When they saw the target, they were to think of the corresponding sound—here, an example was given: “If you see ‘G’, think /g/ as in *gas*.” If the sentence they heard over their headphones immediately following visual presentation of the target contained that sound, they were to press the response button as fast as possible.

The subjects were seated in front of a computer, wearing headphones, their preferred hand resting on the key they would press to record their response. Subjects were informed that only the indicated key was available to record their responses, and that speed and accuracy were important. A trial began with visual presentation of the letter representing the target phoneme in the center of the screen for 1 sec. The screen was left blank for 500 msec. Then, while viewing a blank screen, subjects heard a sentence. 1500 msec after the end of the auditory presentation, the trial ended and a new trial began immediately. The subjects’ pressure on the response key was recorded by a software program from the onset of the stimulus to the end of the item. Reaction times were measured from the onset of target phonemes. Before presentation of the stimuli and fillers, the subjects completed a short training sequence that provided no feedback but gave the subjects time to adapt to the task demands.

Forty-eight undergraduate students from Northwestern University completed the experimental task. Six additional students were tested, but their data were discarded because their error rate was over 10% or because they learned English after the age of five. None of the subjects had any known hearing deficit.

2.1.1.2. Results

Reaction times that were negative or greater than 3 sec were discarded and replaced with the mean reaction time by that subject on the other items. Reaction times greater than or less than 2 standard deviations from the inclusive mean were discarded and replaced with the mean. The misses and outliers represented 5.9 % of the data.

The reaction times were entered into an analysis of variance (ANOVA) by subjects with two factors: grammatical category (N or Adj) and sentence position of the word carrying the target (initial or medial). The analysis revealed a main effect of sentence position ($F(3, 180) = 13.38, p < .001$), no main effect of grammatical category ($F(3, 180) = 0.42, p = 0.5$) and a reliable interaction between category and position ($F(3, 180) = 6.79, p < 0.001$). Mean reaction times for category and position are shown in Figure 3.

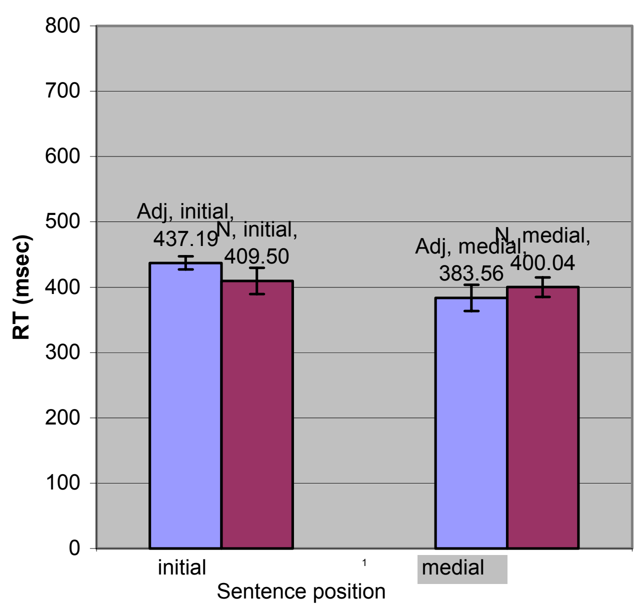

Figure 3: Experiment A mean RTs across sentence position, by word category

Within the adjective targets, the difference in mean reaction times for sentence-initial vs. sentence-medial position was found to be significant (t(90) = 4.2, *p* < .0001). Within noun targets, no significant difference in reaction time was found across sentence position. In sentence-initial position, average reaction times to adjective targets were significantly slower than those to noun targets (t(90)=2.215, *p* < .03) There was no significant difference between reaction times to nouns across position. Figure 4 illustrates these findings.

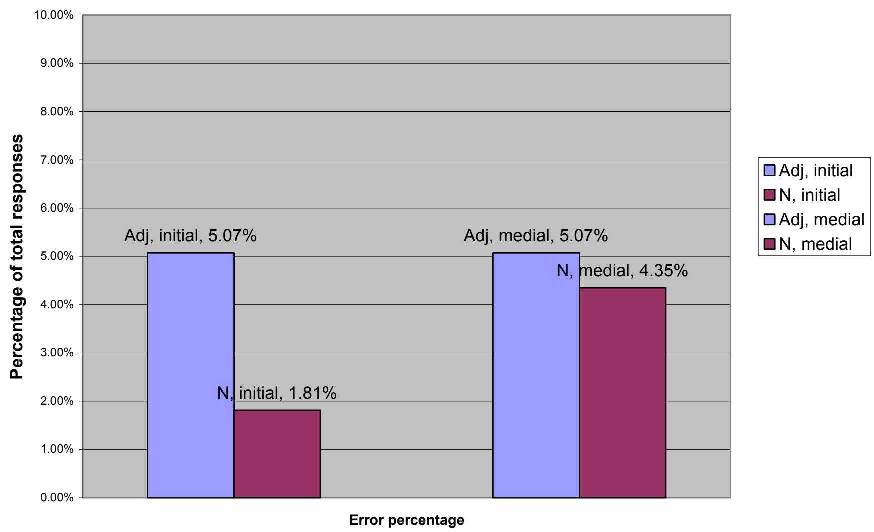

Figure 4: Experiment A Error data, percentage of total responses, by condition

2.1.1.3 Discussion

These results support the function word predictiveness hypothesis, that rapid identification of function words enables listeners to make predictions about the grammatical categories of subsequent words. Christophe et al (1997) showed a rapid function word identification effect, but did not with that experiment account for the grammatically predictive power of function words, simply due to the fact of the word order of the French stimuli.

However, the authors anticipated in their writing that function word stripping could contribute to efficient syntactic bracketing.

In Experiment A, reaction times to phoneme targets in adjectives were significantly slower than reaction times to targets in nouns when the noun phrase containing the target was located at the beginning of a sentence, at an intonational phrase boundary. Table 2 summarizes the results of this experiment and the model experiment.

	Det	**N**		**Adj**
French		RT	>	RT
	Det	**Adj**		**N**
English				
Sentence-initial		RT	<	RT
Sentence-medial		RT	=	RT

Table 2: Summary of results from Experiment A and Christophe et al (1997)

To review, the function-word stripping hypothesis predicts faster reaction times to adjectives than to nouns because the process of function-word stripping was hypothesized to contribute only to lexical access. The function-word predictiveness hypothesis predicts faster reaction times to nouns than adjectives because rapid identification of function words (on this view) contributes to syntactic categorization as well as to lexical access.

The relative slowness of reaction times to sentence-initial adjectives may be interpreted as the absence of the advantage that would be conferred by function-word predictiveness, on which hypothesis the immediately following content word was expected to be the head of the phrase. The relative slowing of reaction times to initial adjectives is consistent with the grammatical category effect we predicted for English.

Christophe et al (1997) reason that word boundaries between two content words are accessed with no special speed advantage, after lexical retrieval is completed. However, this position requires a heterogeneous view of function-word stripping at lexical boundaries: the detection of a content word boundary after a function word is a pre-lexical process, while the detection of a content word boundary after a content word is post-lexical. On this model, the one place where a grammatical category effect should not appear is at the boundary between function word and content word, if this boundary is coded pre-lexically and therefore before characteristics like syntactic category could come into play. However, in Experiment A, this is precisely where we see a grammatical category effect. This is evidence that phoneme detection may not take place until after lexical retrieval is complete. Moreover, it shows that function words predict grammatical category in a way that limits the set of words under consideration during lexical access.

In sentence-medial position, the effect of function-word predictiveness fails to hold for English nouns and adjectives. One interpretation of this result is that the absence of a strong prosodic boundary adjacent to the determiner in the noun phrase neutralized the cue that function words would normally give to categorization. The sentence-medial NPs are located within a VP, where additional acoustic boundary marking that would be present at the start of an isolated sentence (preceding silence, glottalization of initial vowels, etc.) are not available (Beckman and Pierrehumbert 1986, Selkirk 1984). A second interpretation of this result is that the effect observed in the sentence-initial condition was an experimental artifact due to distance from the beginning of the sentence. On this view, participants reacted slower to targets contained in adjectives in the sentence-initial condition simply because the parser works less efficiently earlier in the time course of the sentence. Because the adjectives in these materials were the second word of the sentence, but the nouns were the third word, slower reaction times to adjectives could derive from this difference. By sentence-medial position, such a startup effect would have dissipated, accounting for the lack of the category effect in this condition if syntactic status does not, in fact, confer a processing advantage.

In order to answer that question, a further experiment was designed in which noun phrases of the form [Det N] are compared on this task with the original [Det Adj N] type. This will allow us to distinguish the effect of sentential position from the syntactic category effect predicted by the hypothesis outlined for Experiment A.

2.1.2 Experiment B: Det Adj N vs. Det N

If the slowing for adjectives in Experiment A was due to the parser's expectation that the first content word is likely to be a noun and the head of the phrase, then [Det N] NPs should unambiguously demonstrate a function-word stripping effect when located sentence-initially. If it is true that function-word stripping only performs well at phonological phrase boundaries, then we should again see a leveling of the category effect when NPs are sentence-medial.

2.1.2.1 Method

The method used in Experiment B was identical to that used in Experiment A.

Sample Stimuli

Adjective-initial

1. [The **f**aint noise] indicated that the radio batteries weren't dead yet.

Adjective-medial
2. Ronnie needed [a **f**ast bird] in order to win the school's Pet Olympics.
Noun-initial
3. [A **f**ool] ran out onto the highway to retrieve his pager.
Noun-medial
4. Amy hated [his **f**oot] on her dining table.

Table 3: Experiment B sample stimuli

Sixty-four undergraduate students from Northwestern University completed the experimental task. The data from eight subjects were discarded because their error rate was over 10% or because they learned English after the age of five. None of the subjects had any known hearing deficit.

2.1.2.2 Results

Reaction times were discarded and replaced according to the same criteria as in Experiment A.

As in Experiment A, a significant difference was found for reaction times to target phonemes with respect to sentential position (initial vs. medial): reaction times in the initial condition were significantly slower than reaction times in the medial condition. The reaction times were entered into an analysis of variance (ANOVA) by subjects with two factors: grammatical category (N or Adj) and sentence position of the word carrying the target (initial or medial). The analysis revealed a main effect of sentence position ($F(3, 180) = 13.38$, $p < .001$), but no main effect of grammatical category ($F(3, 180) = 0.42$, $p = 0.5$) and a reliable interaction between category and position ($F(3, 180) = 6.79$, $p < 0.001$). Mean reaction times for category and position are shown in Figure 5.

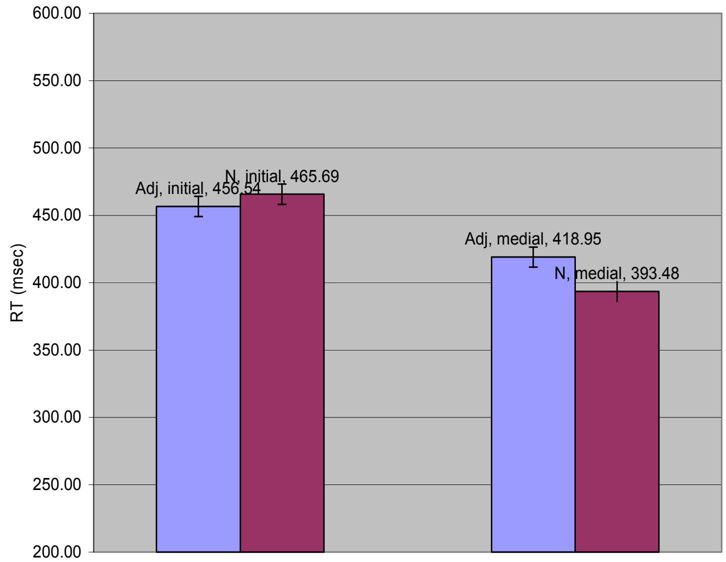

Figure 5: Experiment B mean RTs across sentence position, by word category

Table 4 summarizes the results of this experiment and the initial predictions for it.

	Det	**Adj**		**N**
Predicted		RT	<	RT
English				
Sentence-initial		RT	=	RT
Sentence-medial		RT	<	RT

Table 4: Summary of results from Experiment B and Christophe et al (1997).

2.1.2.3 Discussion

The results of Experiment B support the function word predictiveness hypothesis, that rapid identification of function words enables listeners to make predictions about the grammatical categories of subsequent words. However, examination of the interaction between category and position indicated that the effect of grammatical category was visible only in sentence-medial position, where a paired t-test revealed that targets on nouns were identified significantly faster than targets on adjectives ($p < 0.000$). If, as in Experiment A, reaction times to targets in sentence-initial position reflect a start-up effect, we may suppose that the predicted category effect only obtained further on in the sentence, after the start-up effect had dissipated.

Taken together, the results of Experiment A and B allow us to conclude that function words help construct a fast syntactic parse, giving the listener information about the category of the word that will follow. These results support the conclusion that a process of rapid syntactic structure-building facilitates target recognition, and that hypothesis of function-word stripping in which function words only facilitate fast lexical access cannot fully account for this data. Furthermore, we conclude that function-word predictiveness reflects syntactic processing rather than string probability for the following reason. Because an infinite number of modifiers can precede a noun in English, if the processor projects slots for both word classes based on pure continuation probability, then we would not expect to find an advantage in reaction times to nouns versus adjectives. In fact, Goldsmith (2002) used a bigram distribution model to calculate for the Brown Corpus that nouns are not actually the words most likely to appear either immediately to the right, or two words to the right of the determiner *the*. Rather, the five most common words following *the*, and a total of 12 of the top 20, were adjectives on his calculation. If the role that function words play in predicting upcoming words was due to string probability, we would expect significantly faster reaction times to targets on adjectives, but we did not find this in Experiment B. This lends further support to our conclusion that the effect of function-word predictiveness is due to syntactic processing, in which the parser projects an upcoming noun after encountering a determiner.

Because we assume that a start-up effect distorted the results of both Experiment A and B, we reason that it may be necessary to use an easier and clearly post-lexical task, such as word-spotting, in order to establish an effect of function word predictiveness at various positions in stimuli sentences. The following section outlines word-spotting experiments designed to test the function word predictiveness hypothesis.

2.2 Experiment 1: Det N vs. Aux V

As with Experiments A and B, the goal of these experiments was to investigate whether rapid function word identification contributes only to lexical processing or whether it also contributes to syntactic processing. The experiments in this section were designed to test the function word predictiveness hypothesis using a word-spotting task (McQueen 1996). To maximize the distinctiveness of the syntactic categories being tested, nouns and verbs were selected as word classes that would rarely, if ever, appear in the same environment. With these word classes, groups of function words could be selected that would predict one word class to the exclusion of the other.

To review, Christophe et al (1997) reported an experiment in which adult subjects searched for word-initial target phonemes that fell at the boundary between a function word and a content word or between two content words. Their finding that reaction times were faster for target phonemes between a function word and a content word supported their hypothesis that a first prosodic organization of the input is filled in with function words, which are quickly recognized at the boundary edges of this first-pass segmentation. They concluded that a process of function-word stripping facilitates fast access to a following content word.

Like Experiments A and B, this experiment was designed to test whether function words that are associated with two distinct lexical categories, nouns and verbs, could cause category-specific slowdowns in reaction times during an online speech recognition task.

2.2.1 Design

Monosyllabic frequency-matched nouns and verbs were selected and placed in pairs of sentence contexts that were identical up to the function word preceding the target, after which point the target was grammatical (N or V) or ungrammatical (*N or *V). In half the test items, subjects heard a category-appropriate function word (a determiner or an auxiliary verb) before a target word. In the other half of the test items, subjects heard a function word that was inappropriate for the lexical category of the target. In addition, items were divided into a small-break prosodic category (# break preceding target) and a large-break category (% break preceding target). The experiment was conducted essentially in duplicate for two groups of subjects, the first receiving items (Item set 1) in which noun and verb targets were matched on the basis of wordform frequency from the CELEX database (Baayen, Piepenbrock, & van Rijn 1993), and the second group receiving an item set (Item set 2) containing noun and verb targets matched on lemma frequency. The two types of frequency matches were considered necessary to achieve the best possible controlling of all lexical factors that might affect reaction times to nouns and verbs, considering the extreme differences in the patterns of structural relations inherent to each of these grammatical classes. Furthermore, this being an experiment designed to test adult lexical access speed, the effects of each type of word frequency on reaction time can be explored if a significant difference were to arise in the data from one item set versus the other.

In addition, the sentence contexts containing the targets were written in a way so that they would not semantically prime the target word. In other words, the target words were not considered to be highly semantically related to the sentence contexts they appeared in. The sample stimuli below in Table 5 illustrate this intention.

% boundary		
1a	The wolf, who is steadily howling, can sit if you ask him nicely.	V
1b	The wolf, who is steadily howling, can night if you ask him nicely. *(lemma freq match)*	*N
1c	The wolf, who is steadily howling, can league if you ask him nicely. *(WF freq match)*	*N
1d	Once the donations were counted, their league added up the total profits.	N
1e	Once the donations were counted, their night was just beginning.	N
1f	Once the donations were counted, their sit added up the total profits.	*V
1g	Once the donations were counted, their sit was just beginning.	*V
# boundary		
2a	The shaggy crippled dog will fail to sit while in this class.	V
2b	The shaggy crippled dog will glass to sit while in this class.	*N
2c	The shaggy crippled dog will gown to sit while in this class.	*N
2d	The nursing home would like her gown delivered in the morning.	N
2e	The nursing home would like her glass delivered in the morning.	N
2f	The nursing home would like her fail delivered in the morning.	*V
2g	The nursing home would like her fail delivered in the morning.	*V

Table 5: Experiment 1 sample stimuli

Procedure

Subjects were tested individually or in groups of two in a soundproof room. The subjects received oral instructions that they would participate in a short listening task. Before each sentence, a word would be displayed in the center of the screen, which was the target to be detected. When they saw the target word, they were to remember it. If the sentence they heard over their headphones immediately following visual presentation of the target contained that word, they were to press the response button as soon as they were sure they heard it.

The subjects were seated in front of a computer, wearing headphones, their preferred hand resting on the key they would press to record their response. Subjects were informed that only the indicated key was available to record their responses, and that speed and accuracy were important. A trial began with visual presentation of the target word in the center of the screen for 1 sec. The screen was left blank for 500 msec. Then, while viewing a blank screen, subjects heard a sentence. 1500 msec after the end of the auditory presentation, the trial ended and a new trial began immediately. The subjects' pressure on the response key was recorded by a software program from the onset of the stimulus to the end of the item. Reaction times were measured from the onset of target words. Before presentation of the stimuli and fillers, the subjects completed a short training sequence that provided no feedback but gave the subjects time to adapt to the task demands.

Subjects

30 undergraduate participants from the Northwestern University Department of Linguistics subject pool received item set 1 (noun and verb targets matched on the basis of wordform frequency) and 31 undergraduates received item set 2 (noun and verb targets matched on the basis of lemma frequency). Participants were seated in a soundproof laboratory in front of a computer monitor, wore headphones, and were instructed to strike a button on a button box when they heard the target word that had been presented to them visually on the screen. The

data from four subjects were discarded because their error rate was over 10% or because they learned English after the age of five. None of the subjects had any known hearing deficit.

2.2.2 Results

Reaction times that were negative or greater than 3 sec were discarded and replaced with the mean reaction time by that subject on the other items. Reaction times greater than or less than 2 standard deviations from the inclusive mean were discarded and replaced with the mean for that subject (Christophe, Guasti, Nespor, Dupoux, and Van Ooyen 1997). The misses and outliers represented 5.998% of the total data.

The reaction times from each item set (1=lemma frequency target matches, 2=wordform frequency target matches) were each entered into an analysis of variance (ANOVA) by subjects with three within-subjects factors: grammaticality (grammatical or ungrammatical), lexical category (N or V) and prosodic condition of the sentence carrying the target (% break or # break). The same reaction time data from each item set was also entered into a by-items ANOVA by items with the same factors. In addition, compiled data from both item sets was entered into a by-subjects ANOVA with the same three within-subjects factors and a between-subjects factor of word frequency type (lemma or wordform), as well as entered into a by-items ANOVA

The by-subjects analysis of data from the lemma frequency item set showed main effects of grammaticality $F_1(1,30) = 296.37$, $p < 0.001$, prosodic condition $F_1(1,30) = 9.463$, $p < 0.01$, and category $F_1(1,30) = 4.576$, $p < .05$. In addition, a significant three-way interaction of prosody, grammaticality, and category $F_1(1,30) = 7.5939$, $p < 0.01$, and a significant interaction of prosody and category $F_1(1,30) = 4.3855$, $p < 0.05$ were found. No interaction was observed of either grammaticality and prosody, or grammaticality and category. The by-items analysis of data from the lemma frequency item set showed a main effect of grammaticality $F_2(1,56) = 34.08$, $p < .01$ but no other main effects. No interactions were observed. These results are illustrated below in Figure 6.

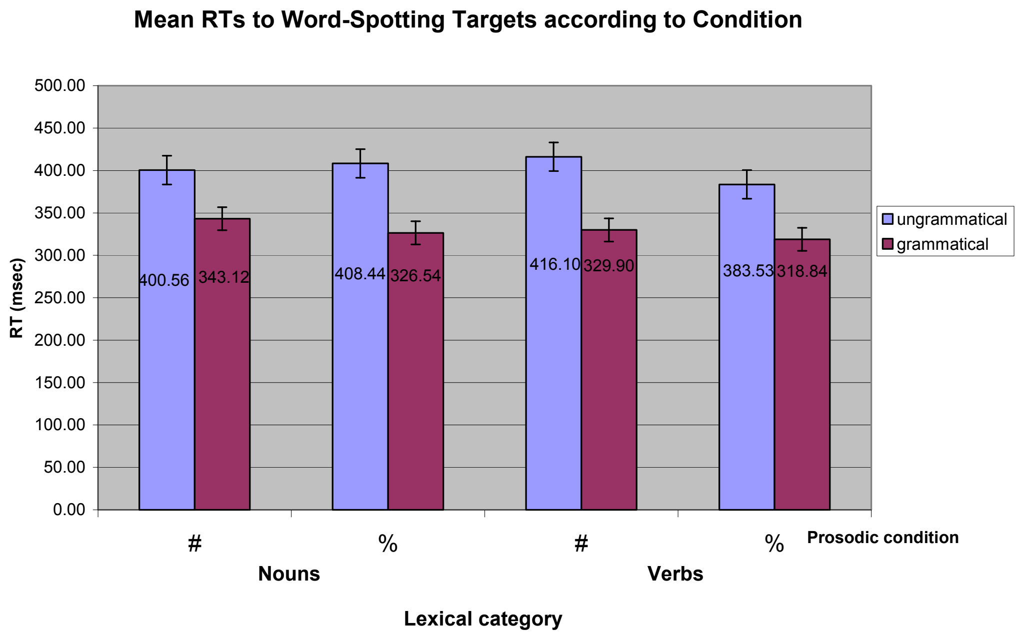

Figure 6: Expt 1 mean RTs across sentence position, by category – Item set 1 (lemma)

The by-subjects analysis of data from the wordform frequency item set showed main effects of grammaticality $F_1(1,29) = 123.19$, $p < 0.001$, prosodic condition $F_1(1,29) = 43.65$, $p < 0.001$, and category $F_1(1,29) = 17.27$, $p < .001$. In addition, a significant three-way interaction of prosody, grammaticality, and category $F_1(1,29) = 3.61$, $p = 0.05$, and a significant interaction of prosody and category $F_1(1,29) = 5.15$, $p < 0.05$ were found. Significant interactions were also observed for grammaticality and prosody $F(1,29) = 4.84$, $p < 0.05$, and for grammaticality and category $F_1(1,29) = 6.43$, $p = 0.01$. The by-items analysis of data from the wordform frequency item set showed main effects of grammaticality $F_2(1,56) = 47.63$, $p < 0.001$ and a marginally significant effect of prosodic condition $F_2(1,56) = 3.09$, $p < 0.1$, but no main effect of category. In addition, a significant interaction of grammaticality and category $F_2(1,56) = 5.24$, $p < 0.05$ was observed. These results are illustrated below in Figure 7.

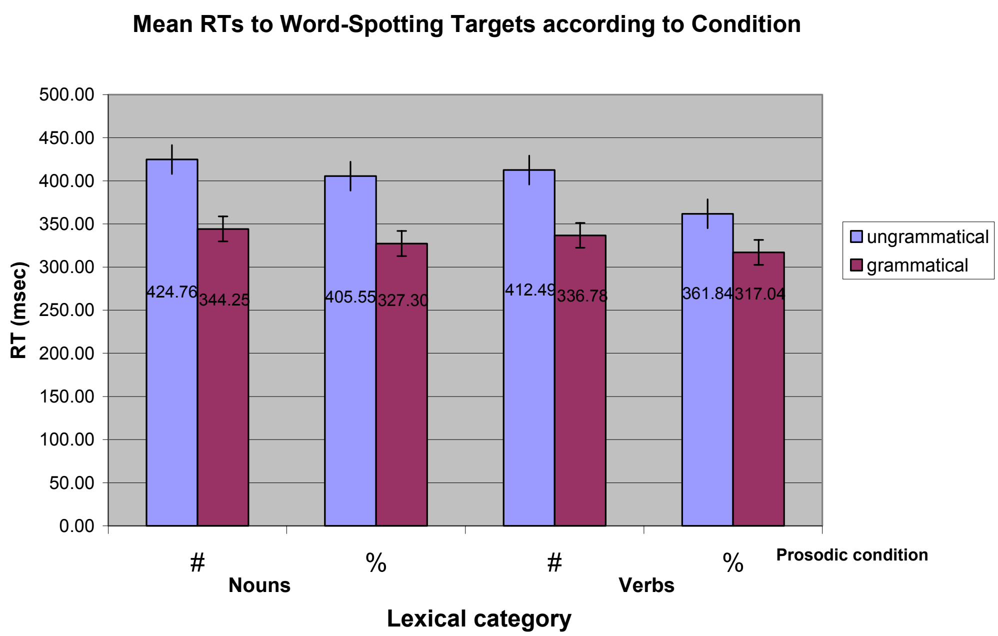

Figure 7: Expt 1 mean RTs across sentence position, by word category – Item set 2 (WF)

The by-subjects analysis of compiled data from both item sets showed main effects of grammaticality $F_1(1,59) = 339.76$, $p < 0.001$, prosodic condition F_1 $(1,59) = 42.52$, $p < 0.001$, and category F_1 $(1,59) = 20.36$, $p < .001$. There was no main effect of type of word frequency. A significant interaction of prosody and category $F_1(1,59) = 8.46$, $p < 0.01$ was found, but no interactions of grammaticality and prosody or grammaticality and category. Other interactions observed were frequency and prosody $F_1(1,59) = 6.19$, $p < 0.02$, and a marginally significant interaction of frequency and category $F_1(1,59) = 3.37$, $p < 0.08$. Significant three-way frequency and prosody interactions were found of prosody, grammaticality, and category $F_1(1,59) = 9.95$, $p < 0.01$; frequency, grammaticality and category $F_1(1,59) = 5.08$, $p = 0.03$; and a marginally significant three-way interaction of frequency, grammaticality and prosody $F_1(1,59) = 3.05$, $p = 0.08$. The by-items analysis of compiled data from both item sets showed main effects of grammaticality $F_2(1,56)=54.01$, $p < 0.001$, and prosodic condition $F_2(1,56)= 4.10$, $p = 0.05$, but no main effect of category. No interactions were observed. These results are illustrated below in Figure 8.

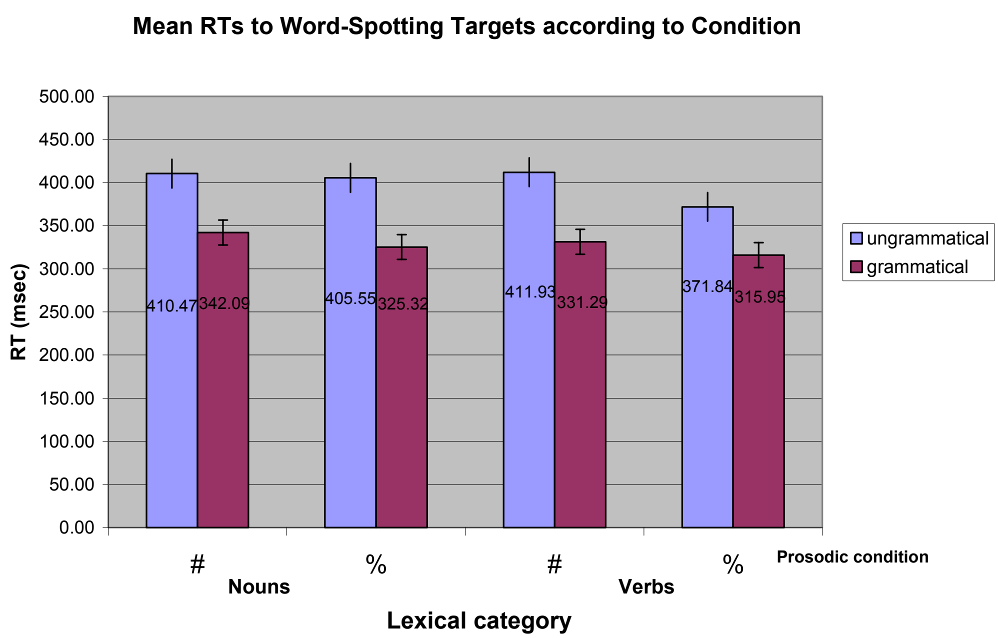

Figure 8: Expt 1 mean RTs across sentence position, by word category – Combined item sets

2.2.3 Discussion

To review, we predicted that subjects would react faster to grammatical targets than to ungrammatical targets, and also that a large preceding prosodic break would facilitate speed of target recognition more than a smaller preceding prosodic break. The following main effects were found in both item sets as well as the compiled data for Experiment 1. First, we found a main effect of grammaticality. That is, subjects responded faster to targets preceded by a grammatical function word than targets preceded by an ungrammatical function word. We also found a main effect of prosodic condition. This means that subjects responded faster to word targets when targets followed a larger prosodic break (%) as opposed to a smaller prosodic break (#). These results are summarized in Tables 6-7 below.

	RT(ms)	**stderr**
Grammatical	330.44	4.99
Ungrammatical	401.68	5.94

Predicted faster

Δ = 71 ms

Table 6: Expt 1 mean RTs by grammaticality of target

	RT(ms)	**stderr**
% (large)	356.2435	5.85
# (small)	375.8746	5.98

Predicted faster

Δ = 22 ms

Table 7: Expt 1 mean RTs by prosodic condition

The main effect of grammaticality observed in Experiment 1 indicates that a grammatical preceding function word helps the listener construct a syntactic parse that speeds up access to words from the expected grammatical category. This result indicates that an additional process is at work during adult lexical access beyond the prosodic processing that leads to function-word stripping; a process of syntactic predictiveness, as predicted by our function-word predictiveness hypothesis. We consider two basic functional claims to account for the speeded word-monitoring behavior of the participants: first, that function word recognition affects only syntactic processing, and that the speeded recognition is due to the quick integration of the following content word into the incrementally-constructed syntactic frame; alternatively, the syntactic processing feeds back to influence the process of content word recognition itself. The results of Experiment 1 appear to support the second, stronger claim. If word identification happened prior to, or concurrent with, syntactic structure building, then we would not expect that syntactic structure would impact a word-finding task.

The main effect of prosodic condition observed in Experiment 1 indicates that a larger prosodic boundary preceding a function word and target facilitates access to the target more than a preceding small prosodic boundary. This supports our hypothesis as well as the predictions of Christophe et al's function-word stripping hypothesis, that a prosodic phrase boundary (signaled by a preceding prosodic break) allows the listener to quickly locate a function word at this boundary, and thus also speed access to a following content word.

We did not predict an overall difference between reaction times to noun targets vs. verb targets. However, in Experiment 1 we did find a main effect of word category, which means that subjects recognized verb targets faster overall than they did noun targets. This result is summarized in Table 8.

	RT(ms)	**stderr**
N (✓ and *)	372.47	6.18
V (✓ and *)	359.65	5.68

Δ = 13 ms

Table 8: Expt 1 mean RTs by word category

The main effect of category was not observed in the by-items analysis of Experiment 1. This means that the category effect is weaker overall than the other main effects; also, the category effect is much stronger in the data from the wordform frequency-matched targets than in the data from the lemma frequency-matched targets. Other effects specific to the wordform frequency-matched subset of the Experiment 1 data will be discussed shortly.

The main effect of category in Experiment 1 is compatible on the surface with the observation that verbs have a variety of properties, including phonological and semantic characteristics in addition to grammatical category, that distinguish them from nouns. These category-specific differences may correspond to verbs being processed differently relative to nouns both by normal subjects and by agrammatic aphasics (Kelly, 1996; Rapp and Caramazza 1998, Shapiro and Caramazza 2003a, Black and Chiat 2003). One possible explanation for the main effect of category may be that the parser makes stronger predictions about upcoming words to integrate into a verb context, than it does about upcoming words to integrate into a noun context. In other words, as the parser generates a syntactic structure for the sentence being processed, upcoming verbs are more strongly predicted than are upcoming nouns.[1] This process would then work straightforwardly for grammatical targets, as verbs are recognized faster due to the stronger prediction set up for them by the parser as the sentences is processed, with no need to revise the structure as words are perceived and integrated into it.

We may then ask whether this process would work in the same way for ungrammatical targets. As a reminder, the aspect of the stimuli sentences in Experiment 1 which made a word target ungrammatical was the syntactic context in which it occurred. Examples of stimuli sentences containing ungrammatical targets are given in (5) – (6):

5) The nursing home would like [her fail] delivered in the morning. *V
6) The shaggy crippled dog [will glass] to sit while in this class. *N

Perhaps listeners are more confident in verb contexts than in noun contexts, and are better able to use them to make predictions about upcoming verbs. This could be related to a structural relation unique to verbs, their syntactic relation to subjects. In his recent work on lexical categories, Baker (2005) identifies the ability of a verb phrase to license a subject in its specifier position as the defining characteristic which distinguishes verbs from other lexical categories. The intrinsic grammatical relation between subjects and verbs could contribute to high predictability of verbs as syntactic structure is generated by the parser. Looking again at example (6):

6) The shaggy crippled dog [will glass] to sit while in this class. *N

[1] This effect could also be accounted for if verbs receive a higher degree of activation, so this explanation is agnostic with respect to type of parsing model.

In example (6), the parser may set up strong predictions for a verb to follow the subject noun phrase that opens the sentence, even before the auxiliary verb is encountered. Recognition of the auxiliary verb then strengthens this prediction, on our function-word predictiveness account. When the ungrammatical target, a noun, is reached, identification is especially slow because the parser strongly predicted a verb from the beginning of the sentence, producing a garden-path effect (Frazier and Rayner 1982). Of course, in example (5),

5) The nursing home would like [her fail] delivered in the morning.*V

the parser should also predict some upcoming complement of the verb *like,* and furthermore that a noun will at some point follow the determiner, but it may be that the effect of the syntactic anomaly on reaction time is less because more different types of continuations may have been possible[2], meaning less revision of projected structure is necessary. Less time needed to revise projected structure would then correspond to faster reaction times to targets in the *V condition of Experiment 1.

Another possible explanation for the main effect of category in the Experiment 1 data is that verbs are less tied to grammatical category in the lexicon than nouns are. This may correspond to the intuition that, when the parser is faced with a grammatical mismatch, it is easier to re-categorize a verb as a noun than to recategorize a noun to a verb. If this is accurate,

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[2] As mentioned previously, Goldsmith (2002) calculates for the Brown Corpus that nouns are not the words most likely to appear immediately to the right or two words to the right of the determiner *the*. Although *the* was not used in function word frames in this experiment or subsequent ones because of its high frequency, Goldsmith's finding lends support to the notion that many continuations are immediately possible even when a determiner signals a noun context.

then listeners may have been faster at recovering from the syntactic anomaly and re-categorizing an ungrammatical verb to fit the noun syntactic frame it appeared in. It would be of interest to compare this intuition to data from the English lexicon on whether there are more instances of nouns which are zero-derived from verbs than there are instances of verbs which are zero-derived from nouns.

In summary, the main effect of category in Experiment 1 suggests a number of interesting conclusions about processing differences between nouns and verbs. Without clearer evidence on the time course of processing the portion of a stimuli sentence that preceded the target, these are offered only as tentative explanations. The category effect will be discussed further on in light of the results of the following experiment.

In Experiment 1, we also observed a reliable interaction of prosodic condition and word category. This interaction was present in the by-subjects analyses of both of the frequency-matched subsets as well as the overall data. We interpret this result to mean that a large preceding prosodic break facilitated recognition of verb targets more than it did for noun targets. This result is illustrated in Table 9 below.

	N (✓ and *)	**V (✓ and *)**
% (large)	366.98	345.51
stderr	6.26	5.35
# (small)	377.96	373.79
stderr	6.11	5.87
	Δ = 11 ms	Δ = 28 ms

↑ Predicted faster

Table 9: Expt 1 mean RTs by word category and prosodic condition

This effect is compatible with any of the previously suggested explanations for the category effect, with the additional account that the facilitative effect of the large prosodic break magnified the category effect, which meant that verbs were recognized faster than nouns.

We will also discuss the interaction of category and prosody with respect to a further interaction observed in Experiment 1. We also observed a reliable three-way interaction of grammaticality, prosodic condition, and word category. This interaction was present in the by-subjects analyses of both of the frequency-matched subsets as well as in the overall data. This interaction resided specifically in the ungrammatical targets, and we interpret it to mean that a large preceding prosodic break facilitated recognition of an ungrammatical verb target more than it did an ungrammatical noun target. This result is illustrated in Table 10 below.

	***N**	***V**	
% (large)	407.04	373.05	Δ = 34 ms
stderr	6.39	5.72	
# (small)	412.25	414.36	
stderr	5.69	5.74	
	Δ = 5 ms	Δ = 41 ms	

↑ Predicted faster

Table 10: Expt 1 mean RTs to *ungrammatical* targets only, by word category and prosodic condition

Examples of stimuli items with ungrammatical targets in the large-break prosodic condition are given in examples (7)- (8):

7) Once the donations were counted, [their sit] added up the total profits. *V

8) The wolf, who is steadily howling, [can league] if you ask him nicely. *N

We interpret the large three-way interaction of grammaticality, category, and prosody to mean that the overall effect of category in Experiment 1 was primarily carried by the ungrammatical verbs. Furthermore, this effect was mostly visible in the large prosodic break condition. This can be interpreted to mean that, when the parser is faced with a significant mismatch such as the syntactic anomaly induced by nouns and verbs in the wrong syntactic contexts, word recognition is generally slowed in every condition. However, if we accept the previously mentioned premise that listeners are faster to recategorize verbs than nouns, then ungrammatical verbs may benefit disproportionately from the facilitative effect of the preceding prosodic break relative to nouns. In other words, the large prosodic break speeds access to the function word at its edge, which in turn speeds access to the following content word. When that content word turns out to be a verb when a noun was predicted by the preceding determiner, the listener is still able to recover fairly quickly by recategorizing the unexpected verb as a noun.

If this is the case, we have to assume that a prosodic boundary facilitates word recognition in a category-specific way, since there was no overall significant interaction between grammaticality and prosody. In other words, a prosodic boundary did not have an overall facilitative effect on the speed of recognition of grammatical targets, as the function word-stripping hypothesis would predict. Instead, the results of Experiment 1 provide evidence that a process of function-word predictiveness appears to operate largely independently of cues to prosodic boundaries.

The observations of other interactions in the analysis of Experiment 1 data can be attributed to various word frequency effects. In the analysis of the wordform data, we found a strong main effect of category, meaning that noun targets were recognized slower than verb targets, as in the compiled data. In the wordform data, we also observed a significant interaction of grammaticality and category. This is illustrated in Table 11:

	N	V
Grammatical	335.78	326.91
stderr	5.50	4.54
Ungrammatical	415.16	387.17
stderr	5.84	5.99

↑ Predicted faster

Table 11: Expt 1 (wordform matched only) mean RTs, by word category and grammaticality

Table 11 shows that ungrammatical nouns were especially slow compared to ungrammatical verbs. The difference between ungrammatical nouns and verbs was slightly greater in the large prosodic break condition, but this interaction was only marginally significant.

Since effects in the wordform-matched data set seem to be carried by the nouns, we can conclude as above that listeners may be faster to recategorize anomalous verbs relative to anomalous nouns. We suggest that the auxiliary is a better predictor of an upcoming verb than a determiner is of an upcoming noun. Consequently, an noun following an auxiliary is the most surprising of the conditions in Experiment 1. Thus, we see the slowest reaction times to the targets in the condition that violates the strongest prediction.

We can also examine a lexical property of nouns in this item set that might affect processing speed. In the wordform frequency-matched item set, target nouns were matched to target verbs on wordform frequency. However, the verbs had a much higher lemma frequency compared to the nouns in this set. Therefore, the nouns in the wordform frequency-matched item set were the targets with effectively the lowest word frequency, leading us to conclude that the slower identification of nouns could be partly due to a frequency effect. This conclusion is supported by the observation of an interaction between the between-subjects factor of type of frequency match and word category, in the analysis of the compiled data. The category effect is mostly visible in the wordform matched item set alone, where noun targets were recognized slower than verb targets. No such effect of word category was observed for the lemma-matched item set. This is illustrated in Table 12.

	N(✓ and *)	V(✓ and *)	
Wf freq	375.47	357.04	Δ = 18 ms
stderr	6.21	5.64	
Lemma freq	369.6622	362.0932	
stderr	6.18	5.73	

Table 12: Expt 1 mean RTs by frequency match type and by word category

The grammaticality effect in the wordform frequency-matched data set was greatest in the nouns, with noun targets recognized even more slowly than were ungrammatical verbs. When the target is ungrammatical, i.e. not in the proper syntactic context, word processing may then be more affected by lexical properties, resulting in slower reaction times due to the lower frequency of the noun targets versus the verb targets. An interaction of prosodic condition with grammaticality was not replicated in the by-items analysis of the same data nor in either the lemma-matched item set data or the compiled data, so we will not offer an explanation for it here.

In the lemma frequency-matched item set, the same main effects and reliable interactions were found as in the overall compiled data, albeit with a much weaker main effect of category. We will conclude from this that matching noun and verb targets on lemma frequency provided the tightest control of lexical factors between nouns and verbs and therefore the best opportunity for us to test our predictions of the effects of grammaticality and prosody. Furthermore, because the same main effects were found in both wordform-matched and lemma-matched data, we will conclude that the type of frequency match is not especially relevant to our hypothesis and we will limit future discussion of this factor.

Because the word-spotting task should be performed at a post-lexical level of processing, the results of Experiment 1 do not distinguish between access to pre- and post-lexical processing as did the phoneme monitoring study reported by Christophe, et al. (1997). However, it is interesting to note that reaction times to whole-word targets following a grammatical function word are about 100ms faster on average than reaction times to phoneme targets following a grammatical function word in Experiments A and B and in Christophe, et al. (1997), perhaps just reflecting a greater processing demand for the phoneme monitoring task, or a delay in when this task in accomplished.

To summarize, the effect of grammaticality expected on the function-word predictiveness hypothesis was found in Experiment 1. The function word preceding a target appears to be aggressively predictive of the grammatical category of the following function word, and this predictiveness appears to function largely independently of the effect of a preceding prosodic boundary cue.

This account is consistent with speech recognition models in which syntactic parsing is incremental and very fast, with syntactic representations being developed quickly as the input is processed. A growing body of research provides evidence for how the parser makes use of syntactic information during the course of sentence comprehension, in contrast to the classic view of syntactic processing (Fodor, Bever, and Garrett 1974) which claimed that syntactic recoding occurred only at the end of each proposition. Proposals about real-time syntactic structure building were first elaborated to explain how the language parser might complete long-distance dependencies like gaps created by movement operations in English, such as wh-movement. Based on findings that reading times were slowed at points in a sentence when a word appeared despite the fact that a preceding moved element had set up an expectation for a gap, studies like Crain and Fodor (1985) and Stowe (1986) developed the hypothesis that in processing, when a moved element is encountered, the processor will immediately prioritize connecting it with the gap created by its movement. Any difficulty in connecting the moved element with a gap should create a slowdown in processing. This approach of forming linguistic dependencies before further disambiguating information is available is referred to as active dependency formation (Phillips and Wagers 2005).

Current evidence to support fast active dependency formation includes the following studies. Aoshima, Phillips, and Weinberg (2004) found that in a head-final SOV language like Japanese, fronted object NPs containing a trace of movement are processed slower than fronted object NPs without a trace of movement. The authors took this as evidence that the parser undergoes reanalysis (evidenced by reading slowdowns) to resolve the filler-gap dependency in advance of the verb in Japanese, providing further evidence that syntactic structure is built rapidly and incrementally during processing. Similar evidence for the fast real-time processing was found by Sturt (2003) for the satisfaction of binding constraints during sentence processing, and by Kazanina, Lau, Lieberman, Yoshida, and Phillips (in press) for the satisfaction of constraints on backwards anaphora.

Two recent studies looking at syntactic anomalies bear particular relevance to Experiment 1. McElree and Griffith (1995) found that, when asked to identify written words presented one-by-one, readers were faster to identify words involved in syntactic anomalies such as category and subcategorization violations than they did from thematic role violations. This provides further evidence that syntactic processing is conducted very quickly by the language parser, earlier than semantic processing. Lau, Stroud, Plesch, and Phillips (2006) conducted an ERP study on processing of ellipsis sentences that showed a strong prediction for an upcoming noun created an early LAN response when the expected noun did not follow. When sentences were modified to reduce the predictability of an upcoming noun, the ELAN effect was reduced, and this difference between the conditions became apparent within 300 ms of the violation, providing further evidence for extremely fast syntactic processing. We can relate this finding to the current study in which the strong prediction for an upcoming noun in Experiments 1 created an immediate slowdown in processing time when a word of the wrong category was encountered, creating a syntactic violation.

These studies create a picture of syntactic structure building which occurs rapidly and incrementally as a sentence is processed. For Experiment 1, the effect that function word predictiveness had on reaction times during sentence comprehension is predicted on an account in which the human language parser makes rapid predictions about upcoming syntactic structure.

However, it is important to address another interpretation of the main effect of grammaticality of Experiment 1, one based on semantic rather than syntactic processing. A serious objection to the preceding account of the predictive syntactic nature of function words could be that reaction times to word targets in ungrammatical syntactic contexts are systematically slower because they are semantically inappropriate. In order to discount this explanation, a follow-up experiment must compare reaction times to semantically improbable targets vs. reaction times to ungrammatical targets like those in Experiment 1. The next question addressed in this research program will be whether the predicted effect in Experiment 1 was due to the grammaticality or to the semantic likelihood of the target words.

2.3. Experiment 2: Det N vs. Aux V, semantic control

Experiment 2 seeks to address a potential confound discussed with respect to Experiment 1 above. Specifically, it aims to address the observation that the results of Experiment 1 could be interpreted as due to the fact that the sentences containing ungrammatical target phrases (**her fail*) are semantically anomalous as well as grammatically anomalous. In order to verify our interpretation of the grammaticality effect of Experiment 1, we need to ascertain that reaction times to semantically unlikely targets are not just as slow as ungrammatical targets.

A large body of psycholinguistic evidence demonstrates that recognition of words is typically faster when target words are preceded by semantically related words, whether the semantic priming occur via a mechanism of spreading activation (Collins and Loftus 1975) or by post-lexical integration (Norris 1986, Ratcliff and McKoon 1988). In order for lexical access to take place, the processor must take into account both the semantic and syntactic properties of an individual word and integrate it into the preceding context, but it has not been fully established whether semantic and syntactic processing act conjointly or in parallel during the course of lexical access. A number of studies have found evidence that the effects of semantic and syntactic anomalies on the speed of processing can be distinguished using ERP methodology (Osterhout & Holcomb 1992; Ainsworth-Darnell, Shulman, & Boland 1998; Friederici, Steinhauer, & Frisch 1999), suggesting that for the purpose of Experiment 2, we may be able to separate the effects of semantic anomalousness from those of the syntactic anomalousness in Experiment 1, by some careful controlling of the semantic properties of the stimuli sentences.

The results of Experiment 1 were taken as evidence that a grammatical preceding function word speeds access to a following content word, and that this effect is greater when it coincides with an intonational phrase boundary. However, the participants may have been slower to respond to the ungrammatical targets because a noun following an auxiliary and a verb following a determiner create very semantically anomalous sentences as well as ungrammatical ones. Experiment 2 therefore aims to manipulate the semantic content of the carrier sentences to create highly semantically anomalous contexts in which to place the target words. In this way, the sentences containing grammatical targets and the sentences containing ungrammatical targets should provide equally poor semantic cues to a plausible continuation and thus level out the effect of the anomalousness of the ungrammatical targets. If participants in Experiment 2 still respond faster to grammatical targets than ungrammatical targets regardless of semantic plausibility, we can strengthen the case that our effect is due to the syntactic predictiveness of function words and not to purely semantic processing.

2.3.1 Design

First, target words used in the stimuli of Experiment 1 were checked in University of South Florida Free Association Norms database (Nelson, McEvoy, & Schreiber 1998) for any semantic association with content words in their carrier sentences. None of the target words was listed as a free associate of any of the content words in its target sentence.

Then, sentences from Experiment 1 were scrambled to create even more semantically unlikely contexts for the targets. The sentences were scrambled by combining the part of the sentence containing the target word with a sentence context previously used for a different target. Examples (9) and (10) illustrate how a sentence from Experiment 1 was altered to create a less semantically natural sentence for Experiment 2, while preserving the same function word-target frames and sentence continuations of Experiment 1.

<u>Experiment 1 grammatical stimuli sentence:</u>

9) The wolf, who is steadily howling, [can sit] if you ask him nicely.

<u>Experiment 2 grammatical stimuli sentence:</u>

10) The wolf, who is steadily howling, [will send] you a subscription form

This permitted the tightly constrained list of targets to be re-used, while the contexts were stripped of as much semantic naturalness as possible.

With these changes, the stimuli for Experiment 2 were created on the model of those for Experiment 1. As in Experiment 1, the stimuli consist of monosyllabic frequency-matched nouns and verbs placed in sets of sentence contexts that were identical except for the function word preceding them (grammatical or ungrammatical). In half the test items, subjects hear a category-appropriate function word (a determiner or an auxiliary verb) before a target word. In the other half of the test items, subjects hear a function word that is inappropriate with the lexical category of the target. In addition, items are divided into a small-break prosodic category (# break preceding target) and a large-break category (% break preceding target).

Sample stimuli

Large-break (%) boundary condition

1a	The wolf, who is steadily howling, [will send] you a subscription form.	V
1b	The wolf, who is steadily howling, [will clay] you a subscription form.	*N
1c	The wolf, who is steadily howling, [will wife] you a subscription form.	*N
1d	Once the donations were counted, [my life] would still be chaotic.	N
1e	Once the donations were counted, [my sky] would still be gray.	N
1f	Once the donations were counted, [my put] would still be chaotic.	*V
1g	Once the donations were counted, [my put] would still be gray.	*V

Small-break (#) boundary condition

2a	The shaggy crippled dog [has stuck] her finger in the paint.	V
2b	The shaggy crippled dog [has desk] her finger in the paint.	*N
2c	The shaggy crippled dog [has den] her finger in the paint.	*N
2d	The secretary found [her gown] delivered in the morning.	N
2e	The secretary found [her glass] delivered in the morning.	N
2f	The secretary found [her fail] delivered in the morning.	*V
2g	The secretary found [her fail] delivered in the morning.	*V

Table 13: Experiment 2 sample stimuli

Procedure

The procedure was identical to that in Experiment 1.

Subjects

20 undergraduate subjects were seated in a soundproof laboratory in front of a computer monitor, wore headphones, and were instructed to strike a button on a button box when they heard the target word that had been presented to them visually on the screen. The data from four subjects were discarded because their error rate was over 10% or because they learned English after the age of five. None of the subjects had any known hearing deficit.

2.3.2 Results

Reaction times were discarded and replaced according to the same criteria as in Experiment 1. The reaction times were entered into an analysis of variance (ANOVA) by subjects with three within-subjects factors: grammaticality (grammatical or ungrammatical), lexical category (N or V) and prosodic condition of the sentence carrying the target (% break or # break), and a between-subjects factor of type of word frequency (lemma or wordform). The by-subjects analysis showed main effects of grammaticality $F_1(1,9) = 230.12$, $p < 0.001$ and prosodic condition $F_1(1,9) = 87.54$, $p < 0.001$, but no main effect of category. There was no main effect of the type of word frequency. A significant interaction of prosody and category was observed $F_1(1,9) = 15.72$, $p < 0.000$ as well as a significant interaction of grammaticality and category $F_1(1,9) = 6.30$, $p = 0.01$. The by-items analysis showed a main effect of grammaticality $F_2(1,56) = 22.93$, $p < 0.001$ but no other main effects. No interactions were observed.

As in Experiment 1, there were two item sets containing items matched on wordform frequency and items matched on lemma frequency. A subanalysis of each item set revealed the same main effects as the analysis on the entire data set. The by-subjects analysis of data from the lemma frequency item set showed main effects of grammaticality $F_1(1,9) = 121.64$, $p < 0.001$ and prosodic condition $F_1(1,9) = 54.283$, $p < 0.001$, and a significant interaction of prosody and category $F_1(1,9) = 8.3203$, $p < 0.01$ were found, as well as a marginally significant interaction of grammaticality and category $F_1(1,9) = 3.1189$, $p < 0.1$. The by-items analysis of data from the lemma frequency item set showed a main effect of grammaticality $F_2(1,56) = 34.08$, $p < .01$ but no other main effects. No interactions were observed.

The by-subjects analysis of data from the wordform frequency item set showed main effects of grammaticality $F_1(1,9) = 100.13$, $p < .001$ and prosodic condition $F_1\ (1,9) = 34.346$, $p < .001$, and a significant interaction of prosody and category $F_2(1,9) = 6.6595$, $p = 0.01$ were found, as well as a marginally significant interaction of grammaticality and category F(1.9)= 2.8612, p=0.1. The by-items analysis of data from the wordform frequency item set showed a main effect of grammaticality $F_2(1,56) = 29.17$, $p < .01$ but no other main effects. No interactions were observed.

The combined results from both item sets in Experiment 2 are summarized in Figure 9.

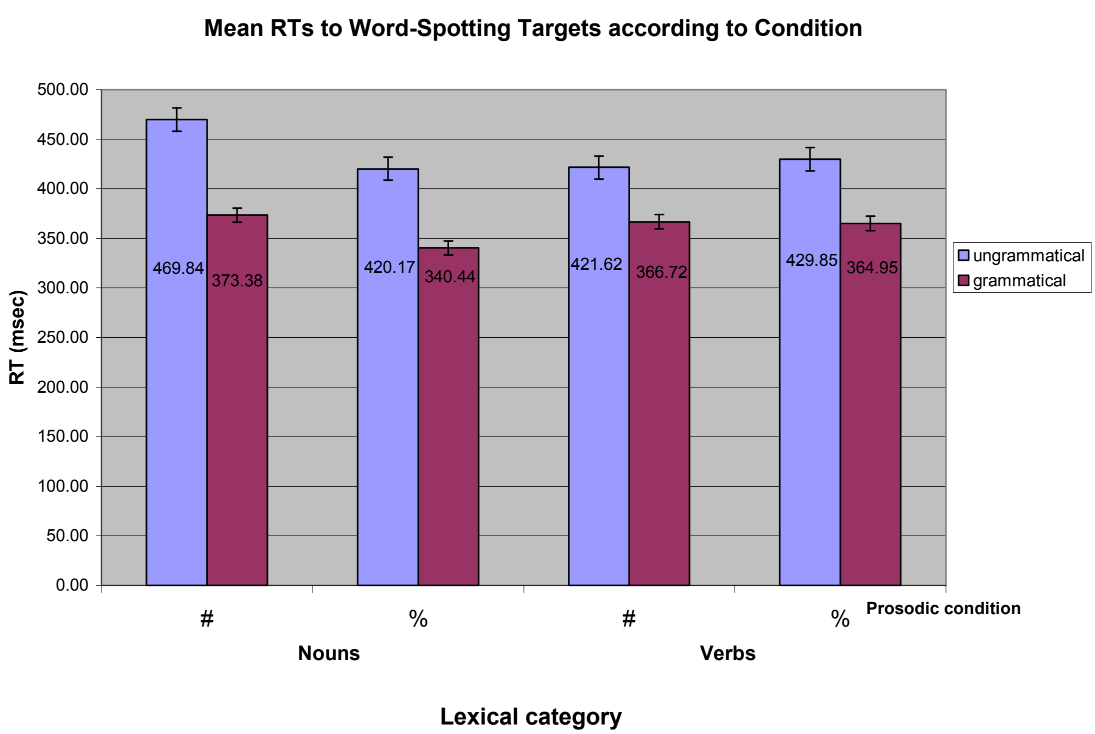

Figure 9: Experiment 2 combined mean RTs across sentence position, by word category

2.3.3 Discussion

Because reaction times to targets located in grammatical sentences were faster than those located in ungrammatical sentences, these results indicate, as in Experiment 1, that a grammatical preceding function word helps the listener construct a syntactic parse that speeds up access to words from the expected grammatical category. This result is illustrated in Table 14.

	RT(ms)	stderr
Grammatical	361.37	6.54
Ungrammatical	435.37	7.79

Δ = 74 ms

Table 14: Experiment 2 mean RTs by grammaticality

Furthermore, because reaction times to targets located after large prosodic boundaries (%) were faster than those after small prosodic boundaries (#), these results also indicate that a larger prosodic boundary preceding function word and target facilitates access to the target more than a preceding small prosodic boundary. This result is illustrated in Table 15.

	RT(ms)	stderr
% (large)	388.85	7.47
# (small)	407.89	7.65

Δ = 19 ms

Table 15: Experiment 2 mean RTs by prosodic condition

Reaction times in Experiment 2 were 30-60 ms slower on average than reaction times in Experiment 1, and standard errors were larger in Experiment 2. We take this as evidence that the semantic implausibility of the stimuli sentences in Experiment 2 slowed reaction times to all word targets.

Because targets were recognized faster overall after a large prosodic boundary than after a small prosodic boundary, we still must conclude that the prosodic difference between the stimuli was real, and that the larger break contributed more to speeding up recognition of a subsequent target. However, the lack of a significant interaction between grammaticality and boundary type, as in Experiment 1, leads us to believe that the syntactic predictiveness of a preceding function word works just as well in the absence of strong prosodic boundary cues as it does with them. In other words, a large prosodic boundary speeds up access to an ungrammatical target just as much as to a grammatical target. In contrast, function words speed or slow access to a following content word based on grammaticality.

In Experiment 2, we also found an interaction between prosody and category. Nouns are identified more slowly inside a prosodic constituent than across a prosodic constituent, relative to verbs. That is, the difference between the small break condition (#) and the large break condition (%) is bigger for nouns than it is for verbs, independent of grammaticality. Within the small-break (#) prosodic condition, participants' reaction times to nouns were significantly slower than to verbs, whereas reaction times to nouns and verbs were roughly equal in this prosodic condition in Experiment 1. This effect seems to be largely carried by the ungrammatical nouns in the small-break condition, which are spotted almost 100ms slower than the grammatical nouns in this condition. This effect seems expected; given that the semantic implausibility of the sentences should reduce the overall predictability of any of the targets, ungrammatical nouns should be recognized slowest on the accounts we have given previously, where ungrammatical nouns are more difficult to recategorize as verbs, and there is no prosodic break to facilitate access.

This result is illustrated in Table 16.

	N(✓ and *)	**V(✓ and *)**
% (large)	380.30	397.40
stderr	7.30	7.68
# (small)	421.61	394.17
stderr	8.32	6.92

Table 16: Experiment 2 mean RTs by prosodic condition and word category

That we did not find a main effect of lexical category is consistent with the fact that our hypothesis does not predict different reaction times to nouns and verbs.   However, an interaction between grammaticality and category appears as it did in Experiment 1 wordform data.

	N	**V**
Grammatical	356.91	365.83
stderr	7.05	6.07
Ungrammatical	445.00	425.74
stderr	7.73	7.90

Table 17: Experiment 2 mean reaction times and tests of significance, category vs.prosody

If ungrammatical nouns are hardest for listeners to recategorize and incorporate into the structure the parser has built, then this result of Experiment 2 is compatible with the account we gave for a similar interaction effect in Experiment 1.

To summarize, the effect of grammaticality expected on the function-word predictiveness hypothesis that was found in Experiment 1 was replicated in Experiment 2, regardless of the fact that Experiment 2 sentences were designed to be semantically less plausible. This is taken as evidence that the effect of grammaticality in Experiment 1 is not due just to semantic processing. As in Experiment 1, in Experiment 2 the function word preceding a target appears to be aggressively predictive of the grammatical category of the following function word, and this predictiveness appears to function largely independently of the effect of a preceding prosodic boundary cue.

2.4. Experiment 3: Semantic ratings of Experiment 1 and 2 stimuli

In order to gather empirical evidence that the sentences used as stimuli in Experiment 2 were indeed semantically worse than those used in Experiment 1, a third experiment was conducted as a series of semantic ratings questionnaires designed to compare sentences from the two experiments. Experiment 3 was designed to test the likelihood of a confound between the effects of the syntactic anomaly and the semantic anomaly produced by the ungrammatical noun and verb targets in Experiments 1 and 2.

2.4.1. Design

Three separate questionnaires were devised to assess both the semantic plausibility of the sentences already used in Experiment 1, as well as to determine whether Experiment 2 sentences were measurably lower in semantic plausibility than even Experiment 1 sentences containing ungrammatical targets. The questionnaires that were given to three separate subject groups are described as follows.

Survey 1

The first questionnaire was designed to directly compare the semantic plausibility of the sentence contexts preceding the targets in Experiment 1 and their scrambled counterparts intended for use in Experiment 2. Only sentences containing grammatical targets (the N and V conditions) were compared to each other. Given a pair of sentences such as (11) and (12), participants were instructed to choose which sentence sounded "more natural."

11) The fish, which Mom bought for my birthday, can grow up to ten feet.
12) The fish, which Mom bought for my birthday, has torn a hole in the box.

Survey 2

This questionnaire was designed to elicit a quantitative rating of semantic naturalness, comparing sentences in Experiment 1 to the sentences constructed for Experiment 2, which were intended to be less semantically natural. One groups of participants completed a questionnaire containing half the sentences from Experiment 1 and half of the scrambled Experiment 2 sentences, and a second group of participants completed a questionnaire containing the other halves of the Experiment 1 and 2 sentences. On a line after each sentence, participants were asked to rate its semantic naturalness on a scale of 1-7. No examples of semantically "natural" or "unnatural" sentences were provided before starting the task. Again, only sentences from the grammatical noun and verb target conditions were compared.

Survey 3

A further questionnaire was designed to directly compare the ungrammatical sentences from Experiment 2 with the grammatical, but semantically unnatural, sentences for Experiment 1. A questionnaire similar to Survey 2, but composed of 50% ungrammatical sentences from Experiment 1 and 50% grammatical, but semantically unnatural, sentences from Experiment 2. The measurement of semantic naturalness was also based on the 1 to 7 rating. Twenty English-speaking adults completed the questionnaire.

2.4.2 Results

Survey 1

The participants who completed this questionnaire (n=15) selected Experiment 1 sentences as "most natural" at a rate of 90%.

Survey 2

Tables 18-20 illustrate the results of Survey 2.

Expt 1 sentences	**Mean plausibility rating** **4.09**	
Expt 2 sentences	**3.15**	p= 0.136

Table 18: Mean ratings of semantic naturalness from Survey 2, first subject group (n=8)

	Mean plausibility rating	
Expt 1 sentences	**4.99**	
Expt 2 sentences	**2.79**	p<0.001

Table 19: Mean ratings of semantic naturalness from Survey 2, second subject group (n=7)

	Mean plausibility rating
Expt 2 sentences	**2.97**
Expt 1 sentences	**4.54**

p < .001

Table 20: Mean ratings of semantic naturalness from Survey 2 (both subject groups – n=15)

<u>Survey 3</u>

The results of Survey 3, which directly compared Experiment 1 ungrammatical sentences to Experiment 2 grammatical sentences, are summarized in Table 21.

	Mean plausibility rating
Expt 2 grammatical	**3.89**
Expt 1 ungrammatical	**1.96**

p < .05

Table 21: Mean ratings of semantic naturalness from Survey 3 (n=20)

Comparison of Survey 2 to Survey 3

The means of the semantic ratings of Experiment 2 grammatical items in Survey 2 and in Survey 3 were entered into a two-sample two-tailed t-test, which gave a p value of $p < 0.001$.

Reanalysis of Experiment 2 effects based on semantic ratings results of Experiment 3

Reaction times from Experiment 1 and reaction times from Experiment 2 were entered jointly into a by-items ANOVA with three within-subjects factors as before: grammaticality of target (yes or no), prosodic condition (% or #), and word category (N or V), and a between-items factor of study (Experiment 1 or 2). We found a main effect of grammaticality, $F_2(1,56) = 8.95$, $p < 0.01$, a marginally significant main effect of prosody, $F_2(1,56) = 3.92$, $p = 0.05$, but no main effect of category. Also, a main effect of study was found $F_2(1,56) = 10.21$, $p < 0.01$. No interactions were observed.

The mean ratings by item of Surveys 2 and 3 were linked to the average reaction times for each item of Experiment 1 and 2. Experiment 2 ungrammatical sentences, which received no direct rating, were set at a rating of 1 (worst possible). The mean ratings and the mean reaction times were entered into a simple linear regression with reaction time as the dependent variable. The adjusted R-square value was 0.062, $F(1,62) = 5.209$, $p < 0.05$, intercept 413.50.

Next, the residual reaction time values from this regression were entered into a new by-items ANOVA with three within-subjects factors as before: grammaticality of target (yes or no), prosodic condition (% or #), and word category (N or V), and a between-items factor of study (Experiment 1 or 2). There was a main effect of grammaticality, $F_2(1,56) = 4.40$, $p < 0.05$, a marginally significant main effect of prosody, $F_2(1,56) = 3.77$, $p = 0.06$, but no main effect of category. Also, a main effect of study was found $F_2(1,56) = 6.03$, $p < 0.05$. No interactions were observed.

2.4.3 Discussion

The results of the first two surveys were taken as evidence that semantic plausibility is significantly worsened for the stimuli for Experiment 2. However, in a direct comparison the ungrammatical stimuli sentences for Experiment 1 were rated as significantly worse on a semantic plausibility rating than the ungrammatical sentences from Experiment 1. This is actually to be expected, since a syntactic anomaly always entails a semantic anomaly, and this anomalousness seems to give rise to a lower semantic rating than grammatical sentences with low plausibility. The result of the Survey 3 leaves open the possibility of an overlap between processing effects of ungrammaticality and semantic anomaly.

To further explore this possibility, we analyzed reaction times from Experiments 1 and 2 together to compare the size of our predicted effects in each study. The same main effects of grammaticality and prosody were found that were present in both Experiments 1 and 2. The weaker effects were consistent with the fact that these main effects were also weaker in each of the separate by-items analyses of Experiment 1 and Experiment 2. Crucially, no interaction of study with grammaticality was observed, which indicates that the size of the effect was the same in both experiments.

Next, the significant level of the R-square value given by the regression of mean semantic ratings on mean reaction times tells us that the semantic ratings accounted for 6% of the variance in reaction times between Experiment 2 and Experiment 1. We can interpret this to mean that semantic plausibility is responsible for some of the size of the grammaticality effect in both experiments, which is understandable considering a semantic anomaly is always entailed by the syntactic anomaly produced by ungrammatical targets in these experiments. The scatterplot and fit line for this linear regression are presented in Figure 10 below.

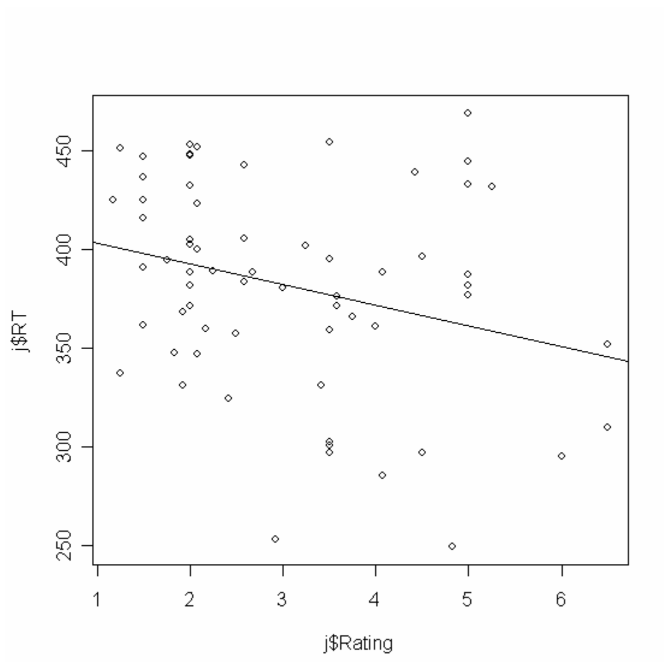

Figure 10: Scatterplot and fit line for linear regression of mean ratings on mean reaction times from Experiments 1 and 2

However, to further strengthen our case the grammaticality effect observed in Experiments 1 and 2 is not due wholly to semantic processing, we entered the residual reaction times from the regression into an ANOVA just like the analysis done on Experiments 1 and 2 raw data. Again, we observed main effects of grammaticality and prosody, indicating that after removing the portion of the reaction time data that was explained by the independent semantic ratings, we still observe a significant effect of the grammaticality of a word target. We interpret this to mean that the effect of grammaticality observed in Experiments 1 and 2 is not due completely to semantic processing, and so must be strongly reflective of the syntactic processing implicated in integrating a target word into the function word frame it appears in.

2.5 Summary and Open Questions

To summarize, this series of experiments has shown that the grammaticality of preceding function word significantly affects the speed of lexical access to a following real-word target. Furthermore, this series of experiments demonstrates that the presence of a prosodic boundary preceding a function word-content word frame speeds up lexical access as shown earlier by Christophe et al (1997).

Experiment 1 showed that the effect of grammaticality of a preceding function word significantly affected subjects' reaction times. Experiment 2 additionally strengthened the case that the difference in reaction times to grammatical and ungrammatical targets was due to the syntactic frame the target occurred in, not wholly to the semantic anomalousness of the target. Experiment 3 attempted to account for the portion of the grammaticality effect observed in Experiments 1 and 2 that was due to semantic processing, and also found that a significant effect of grammaticality was indeed due to syntactic processing.

This program of research on adult sentence processing has aimed to add evidence to the body of research that shows that adults use both prosodic and word-class information to constrain lexical access. A further aim of this type of research is to demonstrate a model of learning, following the reasoning that information available in the speech stream that reliably corresponds with language properties that distinguish one grammatical category from another, may also be used by infants to discover aspects of syntax before their vocabulary of their native language is fully developed.

Therefore, it remains an open question whether infants, at an age where they begin to compile a list of the relevant function morphemes of their native language, can use their knowledge of these words' co-occurrence restrictions to perform a task similar to that completed by adults in Experiments 1 and 2.

CHAPTER 3

The experiments presented in this section are designed to find, for infants, the effect found for adults of function words facilitating fast access to grammatically predicted word targets. By extending these findings to infants, the significance of the previous findings on the interplay of function words and phrase boundaries in lexical access will be broadened to include information on their role in language acquisition. First, I review issues in the literature on grammatical category acquisition that lead to the formation of the questions this dissertation attempts to answer.

To review, the aim of this dissertation is to explore one type of information children may use in acquiring grammatical categories, which is part of the larger question of how children learn words. The prosodic bootstrapping hypothesis claims that children use syntactic context, in conjunction with cues to prosodic phrase boundaries that may coincide with syntactic phrase boundaries, to determine a word's syntactic category. In answering the question of how children learn words, investigating the recognition of function words highlights a special and informative step in the process, situated where prosodic and distributional/contextual cues intersect. The way in which these different types of cues play a role in the recognition of function words, and thus contribute to the role of function words in the acquisition of grammatical categories, is summarized as follows.

First, one particular feature of syntactic context that might be useful to learners acquiring grammatical categories is the functional morphology associated with a given word class. A large body of work has established that children can distinguish function words from content words, even before they are able to produce function words (Gerken, Landau, & Remez, 1990; Gerken

& McIntosh ,1993; Shady, 1996; Shi, Morgan, & Allopenna 1998, Shafer, Shucard, Shucard, & Gerken, 1998; Golinkoff, Hirsh-Pasek, & Schweisguth, 2001; Höhle & Weissenborn, 2003; Shi, Werker, & Cutler, in press; Shi, Marquis, & Gauthier, forthcoming, etc.). Based on the ability to make this distinction, learners can then begin to determine whether function words form subclasses that predict different open-class words.

If the ability to identify function words is firmly present in preverbal infants, it is important to ask how infants are able to learn to do it. Christophe et al (1996, 1997) propose that because function words tend to occur at the edges of prosodic constituents, a language-learning infant could use prosody to determine where in the speech stream a function word is likely to occur (also, Shady & Gerken, 1999; Gerken, 2001).

Having established that infants can recognize function words in continuous speech and distinguish them from content words, the next question to ask is whether infants know the co-occurrence restrictions of function words at an early age, so that they could use this knowledge to draw inferences about the syntactic category of co-occurring content words. Gerken and McIntosh (1993) first showed that infants are aware of these co-occurrence patterns. In this study, infants of 23 to 28 months of age performed better on a picture-identification task when the object noun they were asked to identify was preceded by a grammatical article, in contrast to when the object noun was preceded by either an ungrammatical auxiliary or a nonsense word. These results demonstrated that children are sensitive to the co-occurrence relationships of certain function words and experience comprehension difficulty when these relationships are violated. The discovery that children are aware of these co-occurrence patterns led to the hypothesis that children could use these patterns from a very early age to solve the segmentation and categorization problems of category acquisition discussed in Chapter 1.

More recent studies have further explored the processes by which infants of varying ages may use co-occurrence patterns begin building grammatical categories. Gomez and Lakusta (2004) conducted a study with 12-month-old infants, in which they familiarized the infants to artificial language items consisting of pairs of monosyllabic marker elements, and word-like elements containing either one (Y elements) or two syllables (X elements). In test trials, the infants heard the same marker elements paired with new, unfamiliar wordlike elements of either the X or Y type. They found that infants listened longer to strings from the training language, indicating that the infants had categorized the novel words and distinguished the test items' grammaticality based on their co-occurrence with the marker items paired with each category during familiarization. This study demonstrated that by 12 months, infants already have the ability to generalize categories based on the co-occurrence of functional elements with two word types distinguished by a single feature.

The following two studies report on infants' ability to make grammatical category generalizations based on dependent functional morphology such as In a particularly well-designed study, Gerken, Wilson, and Lewis (2003) familiarized monolingual English-speaking 17-month-old infants to a Russian gender paradigm, from which they withheld a subset of items. During test trials, infants heard either items from the withheld subset of the gender paradigm as well as ungrammatical items in which previously heard stems were inflected with markings corresponding to a different grammatical gender. The results showed that infants were able to discriminate grammatical items from ungrammatical items, none of which they had previously heard, after being familiarized to the gender paradigm for about 2 minutes. However, infants were only able to perform this discrimination when items were double-marked for grammatical gender. The authors concluded that infants can quickly form categories purely by observing co-occurrence patterns in a data from a real human language, without having reference to the meanings of the words or the inflectional morphology.

Gouvea, Aldana, Bell, Cody, de Groat, Johnson, McCabe, Zimmerman, Kim (2005) found evidence that 18 month-olds, but not 15-month-olds, listened longer to passages containing grammatical dependencies of correct number agreement between determiners and nouns. Their study was modeled on the study done by Santelmann and Jusczyk (1998) demonstrating that infants of the same age are sensitive to the grammatical dependency between auxiliary verbs and suffixes on the main verb.

Christophe, Millotte, Bernal, & Lidz (in press) review evidence that identifying function words at phonological phrase boundaries is useful for lexical access, and provide new evidence from infant and adult studies that it is also used to begin constructing a syntactic analysis. In one study, the authors presented French-speaking two-year-olds with an object undergoing an action; one group of infants was taught a novel verb in a sentence composed of just a subject pronoun plus the novel word; another group of infants was taught a novel noun also in a sentence composed of just a determiner plus the same novel word. In a following comprehension task, infants were shown two pictures of the same object, one in which the object performed the familiar action, and one in which the object performed a new action. Infants in the verb group chose the picture of the familiar action when questioned with the novel word, showing that they used the functional morphology that co-occurred with the novel word to categorize it as a verb, and then exploited the tendency of verbs to map to actions. Infants in the noun group chose the picture of the new action, having used the functional morphology to classify the novel word as a noun—either picture fit the criteria, so they showed a classic novelty preference.

In another study, the authors presented French-speaking adults with sentences composed of mostly nonsense words, in which only function words and prosodic information corresponded to the real French language. In one condition, targets were immediately preceded by function words, in the second condition, function words did not immediately precede the targets. Adults had to identify only word targets of the syntactic category specified when the target was introduced. Participants accurately detected words of the requested category based on their co-occurrence with preceding function words in the condition where the function word occurred just before it. In the condition where a function word occurred multiple syllables earlier, participants only responded accurately when a prosodic break immediately preceded the nonword target. This set of experiments illustrates how function words, and also function words in conjunction with prosodic phrase boundary cues, can be used to categorize novel words.

Höhle, Weissenborn, Kiefer, Schulz, and Schmitz (2004) conducted head-turn preference experiments with German-learning infants designed to test whether infants of this age are able to use their knowledge of function words and the word classes they co-occur with to categorize novel words. The authors paired pseudowords *glamm* and *pronk* with either a preceding determiner or subject pronoun for a familiarization phase. One group of infants was familiarized to *glamm* and *pronk* as nouns, another group was familiarized to the same pseudowords as verbs. During test, the infants listened to passages where the familiarized pseudoword was used either as a noun or a verb (with different preceding function words during the test phase). The authors found evidence that 14- to 16-month-olds, but not 12- to 13-month-olds, were able to use a determiner to categorize a following novel word as a noun. In contrast, the predicted verb categorization effect was not found for a novel word following a subject pronoun.

Mintz (2006) used a headturn preference procedure to familiarize 12-month-old infants to sentences containing a novel word in a frequent frame (Mintz 2003) between a function word and a following word. Infants were familiarized to novel words in one syntactic context (either noun or verb), then in test trials heard both sentences where the novel word appeared in the same syntactic context as familiarization, or in a syntactic frame inconsistent with familiarization. The same frequent frames were used in both familiarization and test, and grammatical vs. ungrammatical test items differed only in the nonword inserted in the frame. The results showed that infants listened longer overall to ungrammatical rather than grammatical strings, but analyzed by syntactic category only the difference in looking times between grammatical and ungrammatical verbs was significant. Mintz concluded that distributional information from the frequent frames was the primary factor in the observed categorization effect.

Given this recent evidence that infants have knowledge of the co-occurrence restrictions between determiners and nouns, as well as auxiliaries and verbs, we predict that infants of roughly this age will demonstrate adult-like responses to sentences similar to those used in Experiments 1 and 2.

In Experiments 1 and 2, we showed that rapid function word identification contributes to syntactic processing and not only to lexical processing. The results of Experiments 1 and 2 showed that function words help adult listeners make strong on-line predictions about syntactic categories in a way that speeds lexical access. For Experiment 4 and 5, the function-word predictiveness hypothesis predicts that infants between 14 – 18 months old, who are sensitive to the form of function words in continuous speech, will also use function words to make predictions about the grammatical category of an upcoming content word. In Experiments 4 and

5, we show that infants can use this predictive nature of function words to segment and categorize novel words.

3.1 Experiment 4

The function-word predictiveness hypothesis predicts that infants, like adults, may use the predictive nature of function words to make strong on-line predictions about the grammatical category of an upcoming word. If English-speaking infants of 14 to 18 months of age have adult-like knowledge of function words that co-occur with the syntactic category of nouns, such as determiners, we predict they will categorize a novel word according to its co-occurrence with a real function word, as shown for German-speaking infants by Höhle et al. (2004). Furthermore, we predict that English-speaking infants of this age will be able to use similar resources and a similar procedure to categorize novel words as verbs, using their knowledge of function words that frequently co-occur with the syntactic category of verbs, such as auxiliary verbs.

In Experiment 4, English-speaking infants of 14 to 18 months of age were familiarized to phrases consisting of a function word plus a novel word target. In test trials, they heard sentences containing the same novel words paired with a different function word of the same category, or paired with a function word of the incorrect category. Experiment 4 used a paradigm for presenting speech passages to children known as the Headturn Preference Procedure (HPP), in which infants' looking times to flashing lights that coincide with the playing of a speech stimulus are taken as a measure of their attention to that speech stimulus (Kemler Nelson, Jusczyk, Mandel, Myers, Turk, and Gerken 1995). As in previous experiments that have used this procedure, i.e. Jusczyk and Aslin (1995), we reason that if infants listen longer to the sentences containing familiar words, they must have detected some similarity between what they heard during familiarization and what they heard in test trials. We predict longer listening times to familiar items, rather than novel ones for the following reasons. One reason that infants may prefer to listen to familiar items is because of the variation in the stimulus materials (Jusczyk and Aslin 1995). For example, novel words appear with different function words at familiarization and at test both in the grammatical and ungrammatical test trial types. An additional reason infants may prefer familiar items, or a familiar type of item, is that the task of categorizing novel word targets based on their co-occurrence with function words is more complex than simply recognizing the same item heard at familiarization and test (as in typical HPP studies), causing infants to attend more to similarities that they are able to find between the familiarization and test materials.[3]

We predicted that, after being familiarized to items containing function word –novel word pairs, infants will listen longer to sentences that contain function word-novel word pairs that correspond to the grammatical category of the familiarization phase than sentences that contain novel words paired with a function word of the category not used in familiarization. In other words, if during familiarization infants segment and categorize the novel words as either nouns and verbs based on their pairing with a determiner or an auxiliary, then infants should listen longer to sentences that contain grammatical determiner-noun and auxiliary-verb phrases than sentences that contain ungrammatical auxiliary-noun and determiner-verb phrases.

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[3] Conversely, if infants were familiarized and tested on similar-sounding items repeatedly until they were completely habituated to this type of speech stimulus, we would expect infants to prefer novel items in test trials.

If infants' knowledge of the co-occurrence restrictions of determiners with nouns and auxiliaries with main verbs leads to better recognition of novel targets that follow function words appropriate to the familiarized category, then infants should show mean looking times that are longer to the grammatical stimuli presented in test trials than to the ungrammatical stimuli. This is because we predict that hearing the function-word novel pairs during familiarization will interest the infants in these phrases and cause them to categorize the novel words as either nouns or verbs. Then during test trials, they will prefer to listen to the novel words that occur as the familiarized grammatical category because they recognized the novel words better in continuing speech when they were strongly predicted by a preceding function word.

If infants look longer to grammatical stimuli, we can conclude that infants know these category-specific function words and are using them the way adults do in lexical access, replicating the findings of Experiments 1 and 2. This would then allow us to conclude that infants, like adults, use function words to create expectations of syntactic structure.

3.1.1 Method and Design

Materials

Four monosyllabic pseudowords (keb, zav, pell, dak) were selected. Monosyllables were used to avoid giving potential prosodic cues to the syntactic category of the items (Kelly 1996). The monosyllables were designed to be familiarized uniquely to the infants as either a noun or a verb, two in each category, but were controlled for a range of phonotactic features between the familiarization conditions to further mask any cues to syntactic category: the same pair of vowels was used as the nuclei of the monosyllables in each category, /æ/ and /ɛ/; and place and type of articulation of the onset and coda consonants was roughly balanced between the two categories.

For the test phase, target items were paired with monosyllabic function words (determiner or auxiliary) which were selected from the Bernstein-Ratner CHILDES corpus (mother-child dyads, n=9, ages 1;1-1;11). Function words were ranked for frequency based on usage counts from this corpus in the desired environment (Det + N or Aux + V). Two determiners and two auxiliaries from those that were available in the corpus data were chosen because they could be roughly frequency-matched with each other: *her* (mean count=1.33 per dyad), *my* (mean count=3.1), *will* (mean count=3.3), *can* (mean count=5.0). The combination of either of the determiners with a novel word produced a pseudo-English definite singular noun (*my zav*). The combination of either of the auxiliaries with a novel word produced a possible English verb of the form where the novel word could be the infinitive predicate of the auxiliary, as in the future simple tense (*will dak*). The familiarization phase consisted of either a determiner + noun or auxiliary + verb sequence, as illustrated below in Table 1.

Noun familiarization:

my keb – her zav – my keb – her zav – my keb – her zav – my keb – her zav

Verb familiarization:

can dak– will pell– can dak– will pell– can dak– will pell– can dak– will pell

Table 22: Sample noun and verb familiarization phases for Experiment 4

Each familiarization phase consisted of 24 tokens (this list repeated three times), with token separated by pauses of 600 ms. Each novel word in the familiarization phase appeared with a different grammatical function word than it was heard with during test trials. For instance, during familiarization an infant heard *my keb* but during test heard only *her keb* and *can* keb*.

For the test phase, target items were placed in sets of sentence contexts that were identical except for the function word preceding them (grammatical or ungrammatical conditions). For example, in the total set of experimental items, "*My aunt, who visits us often,* [*AUX* + *pseudoword*] *a slice of cake"* is presented once with a grammatical verb target and once with an ungrammatical verb target. This comparison is split between item sets, each item set presented to a different subject group, so that no infant hears the same sentence context twice within the short span of their time in the sound booth (approximately 5 minutes).

In each group, infants were familiarized and tested with the same novel words, but the set of items they heard during the experiment differed in two ways. First, the pairing of a function word with a pseudoword target was reversed between the two subject groups. For example, subject group 1 was familiarized to [*my keb*] but heard [*her keb*] during test trials, while subject group 2 was familiarized to [*her keb*] but heard [*my keb*] during test trials. Likewise, [*can dak*] and [*will dak*] were distributed in reverse between the two subject groups, and so on with the other pseudoword targets. This was to increase the likelihood that any effect could be attributed to the general classes of noun- and verb-related function words and not to infants' familiarity with any particular function word, either from their own prior exposure or from the familiarization phase of the experiment. Second, test items were divided between the two subject groups so that no infant would hear the same sentence context more than once. For instance, when infants in one subject group heard *"Under the shiny lamp,* [*her keb*] *walked back* *and forth,"* the target pseudoword being in the noun grammatical condition (N), they would never again hear the same sentence frame during the trial, not even containing a different function word and target pseudoword. Likewise, infants in the other subject group would hear *"Under the shiny lamp,* [*my pell*] *walked back and forth,"* in which the target pseudoword was in the noun ungrammatical condition (*N), and would never again hear the same sentence frame during the trial. This arrangement of test items had two different intents: first, to ensure that recent exposure to the leading phrase of a test sentence would not be responsible for affecting infants' interest in or ability to attend to the target phrase; second, to control for any effect of sentence context across the grammaticality conditions (N vs. *N and V vs. *V), so that the vocabulary-acquiring infants' better recognition of one group of words over another (*under the shiny lamp* vs. *before we play the game*, for instance) would not have an unwanted effect on the overall looking times to ungrammatical versus grammatical targets.

Additionally, items presented to participants were subdivided into two different presentation orders. Half of the infants received the two verb familiarization and test blocks before the two noun familiarization and test blocks, and the other half of the infants heard the experimental blocks in the reverse order. Within each experimental block, the familiarization phase was presented first and then the two test trials were presented in randomized order.

Other content words occurring in the sentence contexts were checked against the MacArthur Communicative Development Inventories Lexical Development Norms (Dale and Fenson 1996). The words were screened for matches in the comprehension norms for 14-month-olds. The selected words all showed a similar low frequency of inclusion in the comprehension norms for this age.

The sentence contexts were also designed as the sentences in Experiments 1 and 2, matched for length, stress, and timing up to the point of the onset of the target phrase.

In order to keep the test phase short enough for infants to be able to complete the experiment, the prosodic break condition from Experiments 1 and 2 was eliminated. The prosodic condition in which the largest effect was observed in Experiment 1, the large prosodic break (%), was used for all the stimuli in this experiment. Based on both the results of my Experiments 1 and 2 and on the findings of Christophe, et al. (1997), the easily recognizable prosodic break preceding the target phrases will provide the optimal prosodic environment for infants to recognize function words and utilize their distributional knowledge of the content word classes they co-occur with.

In half the test items, subjects heard a function word preceding the target novel word, either a determiner or an auxiliary verb, which is grammatically compatible with the syntactic category of the familiarization phases. These test trial types were labeled as grammatical noun or grammatical verb (N or V). In the other half of the test items, subjects will hear a function word preceding the pseudoword target that is incompatible with the syntactic category of the familiarization phases. These test trial types were labeled as ungrammatical noun or ungrammatical verb (*N or *V).

An experimental trial for an individual participant consisted of eight test trials, four grammatical and four ungrammatical, divided into four blocks. Each experimental block began with a familiarization phase that was followed by two test trials presented in randomized order. A sample set of items presented to a participant is illustrated below in Table 23.

Example Block 1:

Familiarization: my keb, her zav, my keb, her zav...

Test Trial 1: After the morning song, my keb sat on the table. (grammatical, N)

Test Trial 2: The fish that she bought for our house can zav a kiss to his friend. (ungramm, *N)

Example Block 2:

Familiarization: my keb, her zav, my keb, her zav...

Test Trial 1: The wolf, who is awfully mean, will keb if you ask him nicely. (ungrammatical, *N)

Test Trial 2: Before we play the game, her zav should be all clean. (grammatical, N)

Example Block 3:

Familiarization Trial: can pell, will dak, can pell, will dak...

Test Trial 1: His aunt, who visits us often, will pell a slice of cake. (grammatical, V)

Test Trial 2: Because the swing was broken, her dak lay on the ground. (ungrammatical, *V)

Example Block 4:

Familiarization Trial: can pell, will dak, can pell, will dak...

Test Trial 1: Under the shiny lamp, my pell walked back and forth. (ungrammatical, *V)

Test Trial 2: Our puppy, which Marcus found, can dak you a new book. (grammatical, V)

Table 23: Sample Experiment 4 stimuli presented to a single subject group

Each test trial consisted of a single sentence repeated with a separation of 600 ms of silence until the participant looked away from the flashing light for a period of longer than 2 seconds. Allowing infants to hear several sentences per trial may be important for tapping their sensitivity to subtle differences among stimuli such as those in this experiment (Shafer et al 1998).

Stimuli were recorded by a female English speaker, age 30. She was instructed to read the sentences in a playful but clear voice, as if speaking to an infant. The stimuli were digitized (sampling frequency 20,000 Hz, 32 bits mono) and transferred as sound files to the computer controlling the experimental equipment. The items used in the construction of the familiarization and target test phrases are summarized below in Table 24.

<u>Function words selected for the experiment:</u>

her, my, will, can

<u>Pseudowords used as nouns in the experiment:</u>

keb, zav

<u>Pseudowords used as verbs in the experiment</u>:

pell, dak

Table 24: Summary of items critical to the target phrases in Experiment 4

The within-subject factors for Experiment 4 were test trial type (grammatical or ungrammatical) and lexical category (N or V) and the dependent measure in the headturn preference procedure was mean looking time to the flashing light while a given test trial played.

Participants

Twenty-six infants between 14 and 18 months of age were recruited from Northwestern's infant subject pool for participation at the Infant Studies Center. All children's parents were native speakers of English. Participants were assigned to one of the two subject groups described in the materials section above.

Twenty-six infants (12 boys, 14 girls) between 14 and 18 months of age (range: 13.3 to 17.2 months, average=15.02 months) were recruited from Northwestern's infant subject pool for participation at the Infant Studies Center. All children's parents were native speakers of English. Data from an additional thirty-nine infants were excluded from the analysis of the results due to the following reasons: incomplete experimental sessions (n=23), caregiver's interference during the trials (n=2), average listening times under 3 s during a trial (n=10), or technical problems with the experimental equipment (n=4).

Procedure

The method used was a variation of the head-turn preference task (Jusczyk & Aslin 1995, Kemler-Nelson et al 1995). In the current experiment, an initial familiarization phrase was followed immediately by two test trials, and this sequence was repeated four times. During the experiment, the infant was seated on a caregiver's lap in the center of a soundproof booth. The caregiver wore headphones while listening to music to prevent influences on the child's responses. A light was mounted at infant eye level on each wall of the booth; both the left and right lights were covered with an identical translucent toy rubber duckie to encourage infants' attention to the experiment. The lights and rubber duckies were mounted directly above two speakers on the left and right walls of the booth. The infant's gaze was monitored remotely with a video camera mounted behind the center wall directly above the center light. The experimenter initiated trials when the infant gazed at the blinking center light. When the infant attended to the center light, the center light was extinguished and one of the lights on the side began blinking to attract infant's attention; when the infant looked, the experimenter initiated a speech stimulus. The speech stimulus played from the loudspeaker on the same side as the blinking light. The trial continued until infant looked away for a period greater than 2s. If the child looked away for less than 2s, the presentation of the speech stimulus continued, but the time the infant looked away was not counted in the total looking time. When a trial ended, the experimenter initiated a new trial by causing the center light to blink again, repeating the procedure after the infant again oriented to the center.

The experimenter controlled the experiment from a computer located outside the sound booth, initiating and ending the visual and acoustic stimuli from a keyboard while monitoring the infants' behavior via the video feed from the camera, on a separate computer monitor. When the experimenter initiated a trial, she also coded the head-turns of the child online. The session was also videotaped, allowing for an off-line second coding to check the reliability of the first coding. An off-line coding was performed for 100% of the experimental sessions by a second rater. The data from the off-line coding is reported next in the results of Experiment 4.

3.1.2 Results

Participants had average listening times of 8.69 s (SE=.50s) for sentences containing grammatical function word-novel word pairs and 7.60 s (SE=.59s) for sentences containing ungrammatical function word-novel word pairs. Mean looking time from Experiment 4 were entered into a repeated measures 2 x 2 x 2 ANOVA with within-subjects factors of test trial type (grammatical or ungrammatical) and lexical category (noun or verb), and a between-subjects factor of order of block presentation (forward or reverse).

The analysis showed a significant main effect of grammaticality F_1 $(1,24) = 4.71$, $p < 0.05$, and no effect of either lexical category or order of presentation. No interactions were observed. Twenty-one of the twenty-six infants showed the pattern of looking longer to grammatical sentences than to ungrammatical sentences. This result is illustrated below in Figure 11.

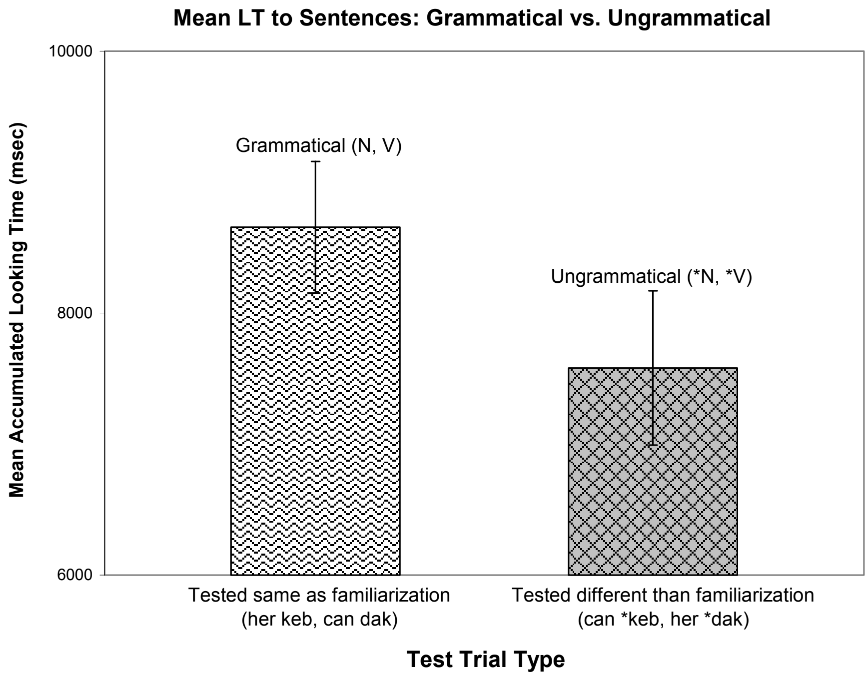

Figure 11: Experiment 4 mean looking times, by test trial type

Figure 12 illustrates the mean looking time data from Experiment 4 organized by lexical category and whether the novel word occurred in test trials with a noun function word (noun frame) or with a verb function word (verb frame)[4].

[4] Note that "frame" in this instance does not refer to Mintz' (2003, 2006) usage of "frame" as two words that co-occur with exactly one word intervening. In Experiment 4 (and 5) stimuli, "frame" refers only to the function word-novel word pairing.

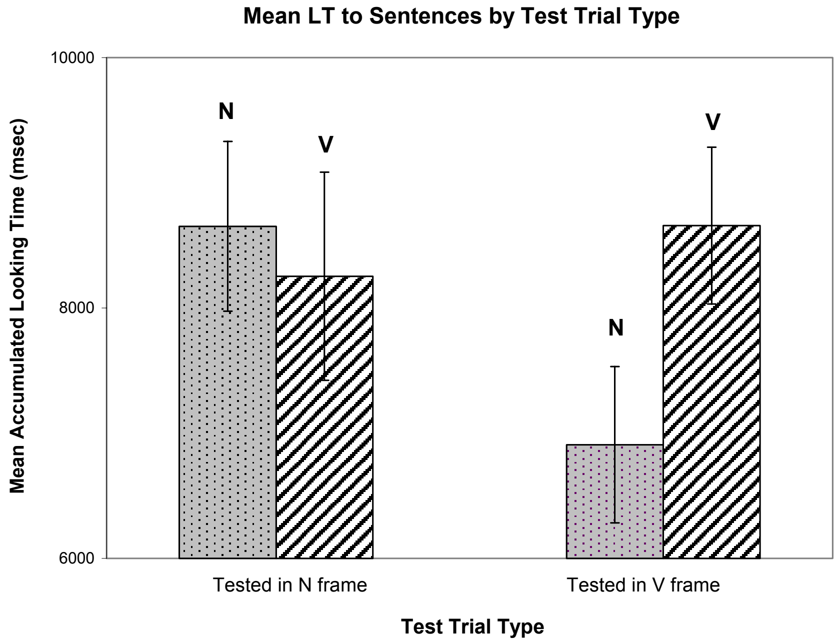

Figure 12: Experiment 4 mean looking times, by category of target familiarization and test trial type

In addition, a pairwise Wilcoxon Signed Ranks Test confirmed the result that infants listened significantly longer to grammatical function word-novel word pairs than to ungrammatical ones ($V=260$, $p<0.05$). In contrast, infants did not discriminate between noun and verb targets overall ($V=135$, $p=0.31$).

3.1.3 Discussion

These results support the function word-predictiveness hypothesis, that infants can use the predictive nature of function words to categorize novel words. To review, we predicted that if infants' knowledge of the co-occurrence restrictions of determiners and auxiliaries leads to better recognition of the novel words in test trial sentences, then infants would look longer to the grammatical stimuli sentences presented during Experiment 4. Furthermore, the lack of an interaction between test trial type (grammatical or ungrammatical) and any other factor indicates that this is a robust, non-category specific effect.

The lack of a significant effect of order of presentation means it did not matter if infants were familiarized first to determiners + novel words or to auxiliaries + novel words. The lack of a significant difference in listening times to determiners + novel words (nouns) versus auxiliaries + novel words (verbs) fits with our hypothesis because we did not predict such a difference. However, as shown in Figure 12, the items that infants looked the least to were sentences containing ungrammatical noun targets, or sentences in which a novel word familiarized as a noun appeared in a verb frame. An example of this sentence type is given in (13):

13) The wolf, who is awfully mean, [will keb] if you ask him nicely. *N

Although the difference between looking times to this sentence type and the other three types was not significant (p = 0.31), it is interesting to note the similarity to a result found in both Experiments 1 and 2. This is illustrated below in Tables 25 and 26.

	N	**V**
Grammatical	356.91	365.83
stderr	7.05	6.07
Ungrammatical	445.00	425.74
stderr	7.73	7.90

↑ Predicted faster

Table 25: Expt 2 mean RTs, by target category and grammaticality

	N	V
Grammatical	11849.19	10939.54
stderr	380.90	356.04
Ungrammatical	9551.50	10728.46
stderr	344.87	388.34

Predicted longer

Table 26: Expt 4 mean looking times, by target category and test trial type

For Experiments 1 and 2, we reasoned that listeners may be faster to recategorize anomalous verbs relative to anomalous nouns. We suggested that the auxiliary is a better predictor of an upcoming verb than a determiner is of an upcoming noun. Therefore, a noun following an auxiliary is the most surprising of the conditions in these experiments. We concluded that the slowest reaction times to the targets occurred in the condition that violates the strongest prediction. This explanation fits well with the trend in *N looking times visible for Experiment 4 in Figure 12. We may conclude that if infants use function words to predict the grammaticality of an upcoming word, *N targets violated the strongest prediction and thus infants were less able to recognize those targets in stimuli sentences.

The equally long looking times to verbs following auxiliaries and nouns following determiners in particular reflect a further finding of Experiment 4. We show here for the first time that infants of this age are able to infer the syntactic category of novel words both in a noun context and in a verb context. Höhle et al (2004) found infants could categorize only novel words in noun contexts, and Mintz (2006) found infants could categorize only novel words in verb contexts. In the case of Höhle et al (2004), the context in which infants were asked to infer a verb category was a subject pronoun –main verb sequence. We reason that a subject pronoun is a poorer predictor of an upcoming verb than an auxiliary is of an upcoming verb, and this is the reason why they did not observe verb categorization in their experiment. In the case of Mintz (2006), the reason that infants did not categorize novel words in both noun and verb contexts may be because infants were younger (12 months) and less knowledgeable of the function word co-occurrences necessary to perform the task. Or, as we suggested earlier, verb contexts may create stronger predictions than noun contexts, resulting in a weaker effect for nouns in that experiment. Because the Mintz (2006) stimuli contained a variety of verb contexts rather than just auxiliary-novel word pairings (in contrast, noun frames consisted solely of determiner_novel word_other word sequences), it may have provided a richer set from which infants could infer the syntactic context, giving an extra advantage to the verb contexts that was not observed in our current experiment.

Given this evidence that infants look longer to grammatical stimuli in Experiment 4, we conclude that infants know these category-specific function words and can use them the way adults do in lexical access, replicating the findings for adults in Experiments 1 and 2. Furthermore, because infants recognized targets based on the category of familiarization and not the specific function-word pairing from familiarization (for instance, they heard *my keb* during familiarization but only *her keb* in a test trial), we can conclude that they perform a true form-class categorization based on their knowledge of the classes of noun-specific and verb-specific function words.

To review, the main effect of grammaticality observed in Experiments 1 and 2 indicates that a grammatical preceding function word helps an adult listener construct a syntactic parse that speeds up access to words from the expected grammatical category. This result indicated that a process of syntactic predictiveness is at work during adult lexical access, expressed by our function-word predictiveness hypothesis. As in Experiments 1 and 2, in Experiment 4 the function word preceding a target has been shown to be strongly predictive of the grammatical category of the following function word.

We now address two separate explanations that may account for infants' preference for sentences containing novel words that occur as the familiarized grammatical category. The first is that they recognized the novel words better in continuing speech when they were strongly predicted by a preceding function word, and did not recognize novel words as well when they followed a function word that predicted a word from a different familiarized category. The second is that they recognized novel words equally in both grammatical and ungrammatical test trial types, but preferred to listen to sentences where novel words were compatible with the familiarized grammatical category. Either explanation for this effect is potentially compatible with the function-word predictiveness hypothesis. Although the head-turn preference procedure measures cumulative looking time and does not provide a clear measure of incremental processing time during test trials, the significant effect of grammaticality indicates that infants were able to use their knowledge of function word co-occurrences on-line while hearing test sentences to predict the grammatical category of an upcoming word.

In Experiment 4, we tested whether infants can infer the grammatical category of a novel word from short phrases in familiarization, then find the word only in matching contexts in full sentences during test trials. The following experiment reversed the familiarization and test phases, while again predicting that infants will categorize novel words according to their co-occurrences with function words. In this way, we can test whether infants can infer the grammatical category of a content word even when function word-novel word pairs are not presented to them isolation.

3.2 Experiment 5

Experiment 4 showed that infants at around 15 months of age are able to categorize novel words based on the information given by a preceding function word in familiarization and test phases. Given evidence that infants are able to perform such a categorization task, we examine a further open question. Can infants still use the cue to grammatical category given by a co-occurring function word when the function word-novel word pairs do not occur in isolation? Previously, both Experiment 4 and Höhle et al (2004) showed that infants can infer grammatical categories of novel words after being familiarized to repetitions of just function word-novel word pairs. In Experiment 5, we test whether they are able to perform the same categorization task when familiarized to function word-novel word pairs that are embedded in short passages.

In Experiment 5, infants are familiarized to short passages of sentences of the type used in test trials in Experiment 4. These passages contain phrases composed of a function word plus a novel word. For Experiment 5 we predict that, after being familiarized to passages containing function word –novel word pairs used repeatedly in one syntactic context (noun or verb), infants will listen longer to short phrases composed of grammatical determiner- noun sequences and auxiliary- verb sequences than to ungrammatical determiner- verb sequences and auxiliary- noun sequences. In addition, we compare their looking times to the familiarized novel words with their looking times to an unfamiliar distractor novel word.

If infants look longer to grammatical phrases than they do to either ungrammatical phrases or unfamiliar words, we can conclude that infants know these category-specific function words and use them to categorize novel words, replicating the findings of Experiment 4 and showing that they can extract this cue from short passages. This would support our conclusion that infants, like adults, use function words to create expectations of syntactic structure.

If infants look less to ungrammatical phrases and distractors, and we find no significant difference between these test trial types, we can take this to mean that infants did not recognize the novel word in the ungrammatical frame any more than they recognized the unfamiliar word. In other words, this would mean that function words help infants access only words which are strongly predicted to follow, replicating the findings for adults in Experiments 1 and 2. If infants look less to ungrammatical phrases, but significantly more to those than to unfamiliar words, we would be able to conclude that infants are able to recognize novel words in both grammatical and ungrammatical test types from their experience in familiarization, but they are sensitive to the difference in grammaticality.

3.2.1 Method and Design

Materials

The same monosyllabic pseudowords (keb, zav, pell, dak), determiners and auxiliaries, and sentence contexts were used from Experiment 4. In addition, for Experiment 5, additional sentences were constructed so that the familiarization phase consists of two five-sentence passages, one in which either *keb* and *zav* is used in a noun syntactic context and one in which either *pell* and *dak* is used in a verb syntactic context.

Each familiarization phase consisted of 5 sentences, with a total length of 20 seconds for each passage. The position of the target novel word was varied in the sentences between beginning, middle, and end. For a given category of familiarization, the same sentence contexts were used in each familiarization phase, but the order of sentences was varied. As in Experiment 5, each content word in the familiarization phase appeared with a different grammatical function word than it was heard with during test. For instance, during familiarization an infant heard “my keb” but during test only heard “her keb” and “can *keb.”

As in Experiment 4, in half the test items subjects heard a function word preceding the target novel word, either a determiner or an auxiliary, which is grammatically compatible with the syntactic category of the familiarization phases. These test trial types were labeled as grammatical noun or grammatical verb (N or V). In the other half of the test trials, subjects will hear a function word preceding the novel word target that is incompatible with the syntactic category of the familiarization phases. These test trial types were labeled as ungrammatical noun or ungrammatical verb (*N or *V).

An experimental trial for an individual participant consisted of twelve test trials, four grammatical, four ungrammatical, and four unfamiliar, divided into four blocks. Each experimental block began with two familiarization phases in randomized order that were followed by three test trials presented in randomized order. Additionally, blocks presented to participants were balanced for presentation order, this time based on the function word paired with novel words during test trials. Half of the infants received the blocks in N-V-N-V order, and the other half of the infants heard the experimental blocks in the reverse order. Again, both familiarization and test trials in each block were presented in randomized order. A sample set of two blocks presented to a participant is listed below in Figure 13.

Familiarization 1

1 My mommy baked the cookies for me and her keb. Then I gave her keb a cookie after I ate one myself. Under the shiny lamp, her keb walked back and forth. Her keb was very tired after walking under the lamp. We sang a song together so her keb could fall asleep.

2 We went to the store to buy a puppy that will dak. Our puppy, which Marcus found, will dak you a new book. He will dak around the room and he will dak all day long. Will he dak if Marcus is watching? We should ask the puppy if he will dak.

Test 1

1) my keb	N
2) my dak	*V
3) my sull	unfamiliar distractor

Familiarization 2

1 My friend Rebecca and my zav came over to my house to play. My zav was very dirty because it was in the sandbox yesterday. Before we play the game, my zav should be all clean. We washed my zav in the bathtub using lots of soap. Then we dried my zav with my own fluffy towel.

2 We went to the store to buy a fish that will dak. The fish that she bought for our house will dak a kiss to his friend. He will dak around the room and he will dak all day long. Will he dak if his friend is watching? We should ask the fish if he will dak.

Test 2

1) can zav	*N
2) can dak	V
3) can gud	unfamiliar distractor

Figure 13: Two sample Experiment 5 blocks presented to a single subject group

Each test trial consisted of a single phrase repeated with a separation of 600 ms of silence until the participant looked away from the flashing light for a period of longer than 2 seconds.

Stimuli were recorded by a female English speaker, age 30. She was instructed to read the sentences in a playful but clear voice, as if speaking to an infant. The stimuli were digitized (sampling frequency 20,000 Hz, 32 bits mono) and transferred as sound files to the computer controlling the experimental equipment. In addition to the test sentences, a list of carrier sentences containing the target words were recorded. Frames of function words plus target pseudowords were then extracted from the carrier sentences to create the test phrases, so the function words would exhibit the characteristic acoustic and prosodic cues of the word class in normal fluent speech, such as vowel reduction. The items used in the construction of the familiarization and target test phrases are summarized below in Table 27.

<u>Function words selected for the experiment:</u>

her, my, will, can

<u>Pseudowords used as nouns in the experiment:</u>

keb, zav

<u>Pseudowords used as verbs in the experiment</u>:

pell, dak

<u>Pseudowords used as unfamiliar distractors in the experiment:</u>

gud, sull, mof, bok

Table 27: Summary of items used in target phrases in Experiment 5

The within-subject factors for Experiment 4 were test trial type (grammatical, ungrammatical, or unfamiliar) and lexical category (N or V) and the dependent measure in the headturn preference procedure was mean looking time to the flashing light while a given test trial played.

Participants

Twenty-six infants (12 boys, 14 girls) between 14 and 20 months of age (range: 13.3 to 20 months, average=15.87 months) were recruited from Northwestern's infant subject pool for participation at the Infant Studies Center. All children's parents were native speakers of English. Data from an additional 15 infants were excluded from the analysis of the results due to failure to complete the experimental session.

Procedure

The method used was a variation of the head-turn preference task identical to that used in Experiment 4. In the current experiment, two familiarization passages were followed by three test trials, and this sequence was repeated four times.

The infants in both subject groups were familiarized with passages containing two determiner-novel word sequences and two auxiliary-novel word sequences. The familiarization was played for a fixed length of time for each infant (20 seconds). Any function word-novel word pair was presented exactly once during the experiment.

3.2.2 Results

Participants had average listening times of 11.52 s (SE=.72s) for grammatical function word-novel word pairs, 7.97 s (SE=.70s) for ungrammatical function word-novel word pairs, and 8.05 s (SE=.48s) for function word-unfamiliar word pairs. Mean looking times from Experiment 5 were entered into a 3 x 2 x 2 repeated-measures ANOVA with within-subjects factors of test trial type (grammatical, ungrammatical, unfamiliar) and lexical category (noun or verb), and a between-subjects factor of order of block presentation (forward or reverse).

The analysis showed a significant main effect of grammaticality F_1 (2, 48) = 14.09, $p < 0.001$, and no effect of either lexical category or order of presentation. No interactions were observed. Twenty of the twenty-six infants showed the pattern of looking longer to grammatical sentences than to ungrammatical sentences.

In addition, pairwise comparisons were conducted between each of the test trial types. For grammatical vs. ungrammatical test trials, a 2 x 2 ANOVA revealed a significant main effect of test trial type F_1 (1, 24) = 14.62, $p < 0.001$, and no effect of either lexical category or order of presentation. No interactions were observed. For grammatical vs. unfamiliar test trials, a 2 x 2 ANOVA revealed a significant main effect of test trial type F_1 (1, 24) = 18.20, $p < 0.001$, and no effect of either lexical category or order of presentation. No interactions were observed. For ungrammatical vs. unfamiliar test trials, a 2 x 2 ANOVA revealed no main effect of test trial type and no effect of either lexical category or order of presentation. No interactions were observed. These results are illustrated below in Figure 14.

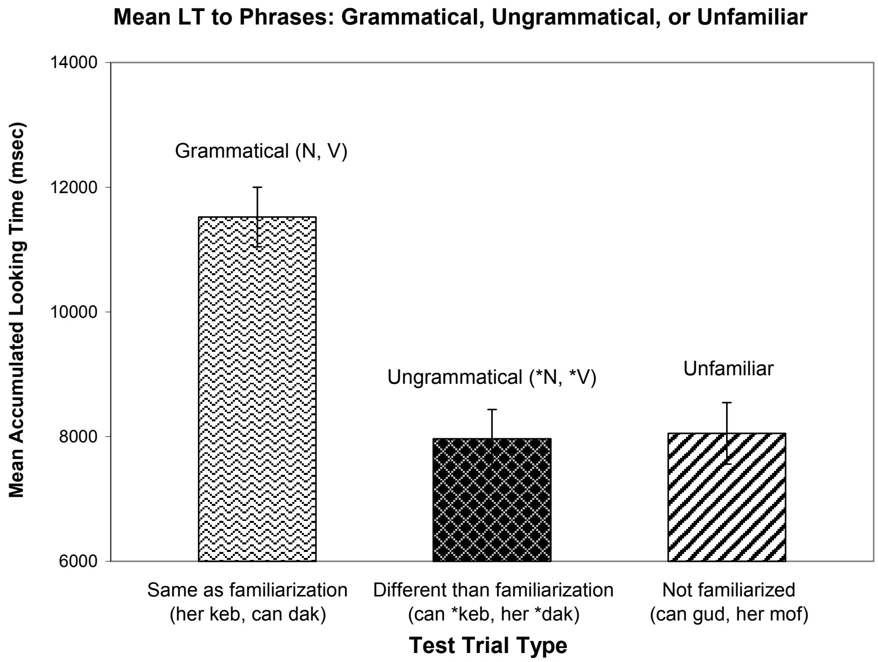

Figure 14: Experiment 5 mean looking times, by test trial type

In addition, mean looking times from Experiment 5 were entered into a 2 x 2 ANOVA with within-subjects factors of syntactic frame type (grammatical or ungrammatical) and lexical category (noun or verb). A reliable interaction of syntactic frame and target category was found, F_1 (1, 24) = 14.62, p < 0.001. Figure 15 illustrates the mean looking time data from Experiment 5 organized by syntactic category and whether the novel word occurred in test trials with a noun function word (noun frame) or with a verb function word (verb frame).

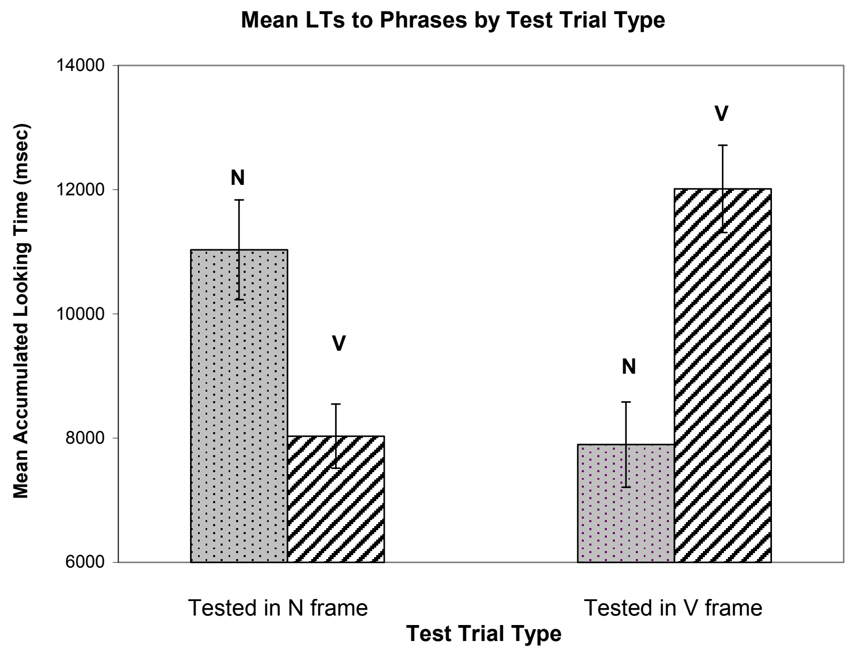

Figure 15: Experiment 5 mean looking times, by category of target familiarization and test trial type

3.2.3 Discussion

Just as in Experiment 4, the results of Experiment 5 support the function word-predictiveness hypothesis, that infants can use the predictive nature of function words to categorize novel words. To review, for Experiment 5 we predicted that, after being familiarized to passages containing function word –novel word pairs used repeatedly in one syntactic context (noun or verb), infants will listen longer to short phrases composed of grammatical function word-novel word sequences than to ungrammatical function word-novel word sequences. Also, we compared their looking times to the familiarized novel words with their looking times to an unfamiliar distractor novel word. Since infants looked longer to grammatical phrases than they did to either ungrammatical phrases or unfamiliar words, we can conclude that infants know these category-specific function words and use them to categorize novel words, replicating the findings of Experiment 4. Furthermore, this shows that they ability to perform the categorization task is not restricted only to when they encounter function word-novel word pairs in isolation, but they can also achieve this by observing co-occurrences during short passages.

Since infants looked less to ungrammatical phrases and distractors, and we found no significant difference between these test trial types, we conclude that infants did not recognize the novel word in the ungrammatical frame any better than they recognized the unfamiliar word. This means that function words help infants access only words which are strongly predicted to follow, replicating the findings for adults in Experiments 1 and 2. This supports the hypothesis of function word predictiveness developed in this thesis, that infants, like adults, use function words to create strong on-line predictions about syntactic structure.

As before, the lack of an interaction between test trial type (grammatical or ungrammatical) and any other factor indicates that this is a robust effect that applies across syntactic categories. The lack of a significant difference in listening times to determiners + novel words (nouns) versus auxiliaries + novel words (verbs) fits with our hypothesis because we did not predict such a difference. Furthermore, the lack of a significant effect of order of presentation means it did not matter if infants were familiarized first to determiners + novel words or to auxiliaries + novel words.

As in Experiment 4, that infants inferred a syntactic category for both novel nouns and novel verbs confirms that infants of this age have knowledge of both the relevant classes of function words. We have shown here for the first time that infants of this age are able to infer the syntactic category of novel words both in a noun context and in a verb context.

As in Experiment 4, because infants recognized targets based on the category of familiarization and not the specific function-word pairing from familiarization (for instance, they heard *my keb* during familiarization but only *her keb* in a test trial), we can conclude that they perform a true form-class categorization based on their knowledge of the classes of noun-specific and verb-specific function words.

To review, the main effect of grammaticality observed in Experiments 1 and 2 indicates that a grammatical preceding function word helps an adult listener construct a syntactic parse that speeds up access to words from the expected grammatical category. In Experiments 1, 2, 4, and 5, the function word preceding a target has been shown to be strongly predictive of the grammatical category of the following function word.

3.3 Summary

In summary, two preferential-listening experiments showed that by 15 months, infants use function words to infer the category of novel words and to better recognize those words in continuous speech. In Experiment 4, infants were familiarized to novel words paired with a determiner or auxiliary verb. In test trials, novel words occurred in sentences with a new function word of the same category as familiarization, or with an inappropriate function word. The results showed that infants listen longer to sentences in which the novel word occurs with a function word of the familiarized category.

In Experiment 5, infants were familiarized to passages containing test sentences from the previous task. In test trials, they heard an appropriate or inappropriate function word paired with the familiarized novel words, as well as an unfamiliar distractor word. The results showed that infants listen longer to novel words when paired with a function word compatible with the familiarized syntactic category, suggesting that, like adults, they recognized novel word targets better when they matched their syntactic expectations.

The results of Experiments 1- 5 allow us to draw strong parallels between infant and adult syntactic processing. We hypothesized that the cue to grammatical category given by function words is robust enough to be perceived and exploited equally by infants and adults. Although the adult listeners in Experiments 1 and 2 performed a different task (word recognition) than infants in Experiments 4 and 5 (word categorization), the greatest factor in the results from both sets of experiments was crucially the function word that preceded a word target. We conclude that function words help adult listeners make strong on-line predictions about syntactic categories in a way that speeds lexical access, and also that infants can use this predictive nature of function words to segment and categorize novel words.

CHAPTER 4

This dissertation began by citing one of the principal concerns for theories of language acquisition: how children so rapidly develop a grammar without explicit instruction as to how to identify the basic elements of this grammar. In keeping with major proposals in the acquisition literature for how children address this problem, we note both that children could benefit from knowledge of syntax to learn the grammatical categories of their language, but likewise that they may need to discern grammatical categories in order to construct a grammar. Solving this bootstrapping problem requires learners to identify cues to grammatical categories that are not logically contingent on having already mastered the lexicon and grammar of their language. A critical marker of grammatical category that has been widely acknowledged for its reliability, availability, and demonstrated recognition by young infants is the functional morphemes of a language. For that reason, the goal of this dissertation has been to refine our understanding of how function words guide the acquisition and processing of syntax.

This dissertation develops the proposal that infants use their early knowledge of function words to bootstrap grammatical categories and to project syntactic structure while processing language input. The current series of studies provide evidence that by the middle of their second year, children have developed sufficient knowledge to classify an unfamiliar word as either a noun or a verb after only a brief exposure to it in conjunction with English function words. These studies also show that by 15 months, infants have constructed abstract grammatical categories organized around the set of function words co-occurring with the elements in these categories. These studies thus add to the literature by demonstrating that children indeed develop knowledge of grammatical categories prior to the complete acquisition of a lexicon, and appear to use this knowledge to make predictions about the syntactic structure of the incoming speech stream.

To add support to this notion, this series of studies also provides evidence that adults use the predictive nature of function words to make an on-line conjecture about the grammatical category of a word they have yet to recognize. Consequently, this dissertation also adds to the literature by drawing a parallel between the acquisition of syntax by infants and the processing of syntax by adults. Our analysis of the results of the studies reported here is based on the premise that the cues that adults use to make rapid grammatical decisions about individual sentences are the same cues that infants use to make decisions about the abstract nature of their grammars. We take for granted some form of the continuity hypothesis, that a child's grammar is endowed with all of the same representational distinctions contained by the adult grammar. For that reason, one of the aims of linguistic theory is to account for the trajectory from an infant's initial language exposure to an adult's fully developed grammar. Although adults may develop greater efficiency that makes some acquisition strategies obsolete, we assume that any robust language regularity is a good candidate for use in language comprehension by both children and adults. The evidence given by this dissertation for how one feature of language is used by infants and adults for two distinct tasks adds to the understanding of the system that underpins both child and adult grammar and suggests that there may be a causal link between the cues that learners use to build a grammar and the cues that parsers use to identify the structure of an individual sentence.

In summary, the experimental evidence set forth in this dissertation underscores that the same information used by adults to predict syntactic structure on-line is also used by infants to build grammatical categories. This supports the idea that a theory of acquisition should give a prominent role to early knowledge of function word co-occurrence patterns as a bootstrap into grammatical categories.

4.1 Review of results of the current study

This dissertation investigated the role of function words in syntactic processing by studying lexical retrieval in adults and novel word categorization in infants. Christophe and colleagues (1997, in press) found evidence that function words help adults and infants quickly recognize a word and infer its syntactic category. Experiments 1-3 of the current study have additionally shown that function words also help adult listeners make a fast prediction about syntactic category of an upcoming word. How is it that adults come to use function words to make this type of prediction? We reason that this adult knowledge may derive from the process of learning language. Experiments 4-5 of the current study provide evidence that an infant learns function words and hypothesizes that they are predictive of function words on the basis of their experience with the language input. Further experience with the language input gives them no reason to discard this hypothesis, so that adult speakers continue to use the predictive nature of function words to guide language processing.

We now review the findings of the current series of studies. Experiments 1 and 2 tested whether mismatching function word-content word pairs could cause category-specific slowdowns in an adult word-spotting task. Adults identified targets faster in grammatical contexts, also, a larger preceding prosodic break facilitated target access more than a smaller break. We take these results to suggest that a preceding function word helps the listener construct a syntactic parse that is capable of affecting the speed of word identification; though listeners were asked only to perform the lexical task of monitoring for certain words, their behavior was influenced by the syntactic information provided by the preceding function word. Thus, this dissertation contributes detail to the interactive aspects of current models of sentence comprehension; this dissertation adds to evidence that the information about syntactic phrases that is carried by function words is accessed prior to lexical selection. A third experiment measured independent semantic ratings of the stimuli used in Experiments 1 and 2, supporting the conclusion that the observed grammaticality effect mainly reflects syntactic, and not semantic, processing. Experiment 1 showed that the effect of grammaticality of a preceding function word significantly affected subjects' reaction times. Experiment 2 additionally strengthened the case that the difference in reaction times to grammatical and ungrammatical targets was due to the syntactic frame the target occurred in, not wholly to the semantic anomalousness of the target. Experiment 3 attempted to account for the portion of the grammaticality effect observed in Experiments 1 and 2 that was due to semantic processing, and also found that a significant effect of grammaticality was indeed due to syntactic processing.

Next, two preferential-listening experiments show that at 15 months, infants use function words to infer the category of novel words and to better recognize those words in continuous speech. First, infants were familiarized to novel words paired with a determiner or auxiliary verb. In test trials, novel words occurred in sentences with a new functor of the same category as familiarization, or with an inappropriate functor. The results showed that infants listen longer to sentences in which the novel word occurs with a functor of the familiarized category. In the next experiment, infants were familiarized to passages containing test sentences from the previous task. In test trials, they heard an appropriate or inappropriate functor paired with the familiarized pseudowords, as well as an unfamiliar distractor word. The results showed that infants listen longer to novel words when paired with a functor of the familiarized syntactic category, suggesting that, like adults, they recognized targets better when these matched their syntactic expectations.

Experiments 4 and 5, which adapt the task demands of Experiments 1 and 2 to an infant head-turn preference procedure, examining how 14- to 18-month olds use determiners and auxiliaries to categorize novel words. In Experiment 4, infants were familiarized to phrases consisting of a real function word (a determiner or an auxiliary) paired with a novel monosyllabic word. They then heard sentences in which the familiarized nonsense words were used in a syntactic context appropriate to a noun or verb, preceded by a different function word than the one used during familiarization. The results showed that infants listen longer to sentences in which the novel word occurs with a function word from the same category used during familiarization. In Experiment 5, infants were familiarized to passages containing test sentences from the previous task. In test trials, they heard an appropriate or inappropriate functor paired with the familiarized pseudowords, as well as an unfamiliar distractor word. The results showed that infants listen longer to novel words when paired with a functor of the familiarized syntactic category, suggesting that, like adults, infants recognized words targets better when they matched their syntactic expectations. These results fit well with the results of recent studies that also find evidence for infants' ability to categorize novel words. In addition, we have shown here the first evidence of infants' categorization of novel words as both nouns and verbs during the same task. Having reviewed the results of Experiments 1-5, we next discuss the contribution of these experiments relative to previous knowledge about the potential role of function words in lexical access and syntactic processing.

4.2 Review of research that foregrounded this study

This dissertation began by discussing the findings of Christophe (1997), that adults use function words at prosodic phrase boundaries to constrain lexical access, a process they called function-word stripping. As reviewed in Chapters 1 and 2, the authors conducted an experiment in which adult subjects searched for word-initial target phonemes that fell at the boundary between a function word and a content word or between two content words. They varied the phoneme-finding task for their two subject groups: one group was instructed to find the target phoneme wherever it occurred in the sentence; the other group was asked to respond to the target only if it occurred at the beginning of a word. The results revealed a significant interaction between task and target position: when the target was on the noun, immediately following the determiner, subjects were equally fast at both tasks. But, when the target was on the adjective, following the noun, subjects were slower to perform the word-initial task than the generalized task. The authors concluded that a word boundary following a function word is more readily available. Their finding that reaction times were faster for target phonemes between a function and a content word led them to hypothesize that a first prosodic organization of the input is filled in with function words, which are quickly recognized at the boundary edges of this first-pass segmentation. A process of “function-word stripping” produces fast access to a following content word and speeded recognition of a target phoneme located in it.

Christophe et al’s (1997) finding of a rapid function word identification effect gave evidence of the useful role function words might play in quickly focusing learners’ attention on a content word, thereby perhaps facilitating their learning of these lexical items and further helping them to notice the co-occurrence patterns between these content words and the function words that they quickly stripped off. However, their experiment did not account for the grammatically predictive power of function words, simply due to the fact of the head-final word order of the French stimuli. That is, in the French noun phrases used in that experiment, the determiners always directly preceded the head noun of the phrase, even when a modifying adjective was also present in the noun phrase. However, the authors anticipated in their writing that function word stripping could contribute to efficient syntactic bracketing, and have conducted further experiments to test this contribution (Christophe, Millotte, Bernal, and Lidz, in press).

With the purpose of adding to the literature on this particular area of syntactic processing, this dissertation has presented the findings of Experiments 1-5 as support for the hypothesis we made to modify and expand on the predictions made by the function word stripping hypothesis. This new prediction was expressed as the function word predictiveness hypothesis, that the rapid identification of function words enables listeners to make predictions about the grammatical categories of subsequent words.

4.3 Summary of the contribution of the current study

What has been shown here is that function words also help adult listeners make strong on-line predictions about syntactic categories in a way that speeds lexical access. Furthermore, infants can use this predictive nature of function words to segment and categorize novel words. In this dissertation, we examined the usefulness of the function words determiners and auxiliaries as a bootstrap into grammatical category acquisition. Since infants may learn to recognize these words via a combination of distributional information (Jusczyk and Kemler Nelson 1996, Gerken 1996, Morgan, Allopenna, and Shi 1996 *inter alia*), evidence that infants use function words to bootstrap category acquisition supports the idea that infants can begin to solve the circularity problem without first having to learn the meanings of words (Landau and Gleitman, 1985; Gleitman, 1990). If this is the case, infants may begin building grammatical categories as soon as they are able to accumulate that type of relevant information, such as learning to recognize and compile an inventory of function words.

When infants begin to recognize the function words of their own language, they may start compiling them into an inventory. From such an inventory they can begin to notice co-occurrence patterns, for example, that function words often appear adjacently or in fairly regular distributional relationship to the other broad category of words, content words, and furthermore that certain function words only occur with certain content words. On this logic, knowing the function words of their language could give infants an advantage both in recognizing the content words that co-occur with them, and in construing a grammatical category to assign to a particular content word (Maratsos & Chalkley 1980, Braine 1987, Christophe and Dupoux 1996). By first making subcategories of function words, the infant could use those subcategories to construe categories of different words that co-occur with function words. This process could allow infants to begin to sort content words into the grammatical categories appropriate to their language's grammar. This dissertation provides evidence to support these hypotheses by showing that infants at around 15 months of age have knowledge of the function words of their language and can indeed assimilate novel content words into the grammatical categories of their native language. In addition, Experiments 4 and 5 have shown for the first time that infants of this age are able to infer the syntactic category of novel words both in a noun context and in a verb context. This implies that infants have early knowledge of abstract syntactic categories, contrary to the proposal that early linguistic knowledge consists only of item-specific lexical representations (Tomasello 2000).

To summarize, the main effect of grammaticality observed in Experiments 1 and 2 indicates that a grammatical preceding function word helps an adult listener construct a syntactic parse that speeds up access to words from the expected grammatical category. In Experiments 1, 2, 4, and 5, the function word preceding a target was shown to be strongly predictive of the grammatical category of the following function word.

The ultimate conclusion of this dissertation concerns the relationship between the learner and the parser. The studies reported here provide evidence that information used by adults to predict syntactic structure on-line is also used by infants to build grammatical categories. Perhaps adults use function words to predict grammatical categories during language comprehension because they used it to construct grammatical categories during language acquisition. This observation evokes an interesting parallel between the use of function words during the time span of the incremental processing of language and the use of function words during the time span of the acquisition process. With the evidence presented here, we begin to enhance the picture of the acquisition process by recognizing that the information that learners use to extract information about the grammar is not discarded when learning is completed. Rather, the parser is empowered by this information during the course of rapid structure building. In contrast to a model of acquisition in which the learning apparatus becomes obsolete when the mature grammar is achieved, it appears the adult language parser elegantly maintains the use of just those cues that are favored by the learner.

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APPENDICES

A. Experiments A and B Stimuli

Adjective condition

1. Ronnie needed [a fast bird] in order to win the school's Pet Olympics.
2. [The gray fort] loomed large over the coastline as the pirates approached.
3. Jenny rented [the Greek boat] instead of the Italian gondola at the boat shop.
4. Sarah loved [the sad fish] that swam forlornly around the pond in the backyard.
5. Mother gave him [a neat tool] from the Sears catalog for Christmas.
6. Nick chose [a bright tie] for his interview with the company's CEO.
7. [The faint noise] coming from the radio indicated that the batteries weren't dead yet.
8. [A soft net] is the most important weapon in a butterfly catcher's arsenal.
9. Marcy saw [a tall guy] in the corner and wondered if he'd ask her to dance.
10. Sherri expected [a nude guest] at her beach party, but everyone arrived fully clothed.
11. [The blind search] was called off when the sheriff's department found the body.
12. [The tight skin] of the platypus is highly prized in Australia for wallets and belts.

Noun condition

1. Amy hated it when her brother stuck [his gross foot] in her face.
2. [A bold fool] had run out onto the highway to retrieve his cell phone.
3. [The twelve gifts] that Marcus received on his twelfth birthday were from his grandmother.
4. [The sick guard] was in the bathroom when the jewel thieves snuck past the gate.
5. Harvey faced fifth grade P.E. every morning with [a brave smile].
6. My grandmother prepared [a grand tea] for her visitors every afternoon at 4.
7. The hikers could not decide which of [the nine trails] before them was the shortest.
8. [A nice bath] was the perfect thing to calm Josie's nerves after a murder trial.
9. The farmer gave Billy [a flat seed] to grow his own watermelon patch with.
10. She always kept [her fair nose] out of the sun, because it freckled easily.
11. [The tough neck] of the turtle had protected him from many run-ins with the family dog.
12. The environmental group needed [a safe beach] where they could set up the seal rescue operation.

B. Experiment 1 Stimuli

Subject Group 1 Items

Block A1

1a The wolf, who is steadily howling, can sit if you ask him nicely.

2a The fish, which Mom bought for my birthday, can grow up to ten feet.

7b The rat, which we captured this morning, has path a hole in the box. *N

6b The puppy, which Marcus adopted, may life nose marks on the window *N

3d Before they invented the motor, your boy had the best bike in town.

4d When one of us stopped the commotion, her blood could be seen through the window.

5f In order to master the problem, their lend has to be perfectly clean. *V

6f Since I'm not hosting the party, my send should be happy all winter. *V

9a The shaggy crippled dog will fail to learn while in this class.

10a Miranda Hammersmith will spend the money on the supplies you asked for.

13b No girl in Illinois has church a thousand crabs before March. *N

14b The local head of state may throat us not to panic. *N

11d Marissa vaguely knows my news about his former marriage.

10d The singing group should eat her food before it gets cold.

15f The meanest gossips saw your warn with all its ugly wrinkles. *V

14f My ailing friend could use their bring of room humidifier. *V

BlockA2

3a Her nephew, who brings her the paper, will send you a subscription form.

4a Our neighbor, who seldom comes near us, may lend us some sugar.

8b The club, which was founded by Pilgrims, has blood me to be a good person. *N

5b My aunt, who I go to see yearly, will girl me drive her car. *N

2d Even if someone would listen, my life would still be chaotic.

1d Once the donations were counted, their league added up the total profits.

7f After the promise was broken, her torn could no longer continue. *V

8f Because the inspectors went northward, your let has been lonely for decades. *V

11a The naughty little lad has stuck her finger in the paint.

12a The new believers here may bring a snack to share.

15b The nun in charge of lunch can flight you in the closet if you don't behave. *N

16b Artistic German kids can news their parents for their talent. *N

9d The secretary found your church after he asked for directions.

12d Armand should not have closed their desk without asking them first.

16f The nursing home would like her fail delivered in the morning. *V

13f Matilda Jones picked out my shut to Kalamazoo, Michigan. *V

<u>Block B1</u>

7a The rat, which we captured this morning, has torn a hole in the box.

6a The puppy, which Marcus adopted, may put nose marks on the window

1b The wolf, who is steadily howling, can night if you ask him nicely. *N

2b The fish, which Mom bought for my birthday, can boy up to ten feet. *N

5d In order to master the problem, their shelf has to be perfectly clean.

6d Since I'm not hosting the party, my wife should be happy all winter.

3f Before they invented the motor, your grow had the best bike in town. *V

4f When one of us stopped the commotion, her taught could be seen through the window.*V

13a No girl in Illinois has caught a thousand crabs before March.

14a The local head of state may warn us not to panic.

9b The shaggy crippled dog will glass to learn while in this class. *N

10b Miranda Hammersmith will food the money on the supplies you asked for. *N

15d The meanest gossips saw your throat with all its ugly wrinkles.

14d My ailing friend could use their kind of room humidifier.

10f The singing group should eat her spend before it gets cold. *V

11f Marissa vaguely knows my thank about his former marriage. *V

<u>Block B2</u>

5a My aunt, who I go to see yearly, will let me drive her car.

8a The club, which was founded by Pilgrims, has taught me to be a good person.

3b Her nephew, who brings her the paper, will clay you a subscription form. *N

4b Our neighbor, who seldom comes near us, may shelf us some sugar. *N

7d After the promise was broken, her tribe could no longer continue.

8d Because the inspectors went northward, your girl has been lonely for decades.

1f Once the donations were counted, their sit added up the total profits. *V

2f Even if someone would listen, my put would still be chaotic. *V

15a The nun in charge of lunch can shut you in the closet if you don't behave.

16a Artistic German kids can thank their parents for their talent.

11b The naughty little lad has desk her finger in the paint. *N

12b The new believers here may kind a snack to share. *N

16d The nursing home would like her gown delivered in the morning.

13d Matilda Jones picked out my flight to Kalamazoo, Michigan.

9f The secretary found your caught after he asked for directions. *V

12f Armand should not have closed their stuck without asking them first. *V

<u>Subject Group 2 Items</u>

<u>Block A1</u>

1a The wolf, who is steadily howling, can sit if you ask him nicely.

2a The fish, which Mom bought for my birthday, can grow up to ten feet.

7c The rat, which we captured this morning, has tribe a hole in the box. *N

6c The puppy, which Marcus adopted, may sky nose marks on the window *N

3e Before they invented the motor, your pot had to be washed by hand.

4e When one of us stopped the commotion, her creek was still running quietly.

5g In order to master the problem, their lend has to be trained to stay. *V

6g Since I'm not hosting the party, my send should be stored for next year. *V

9a The shaggy crippled dog will fail to learn while in this class.

10a Miranda Hammersmith will spend the money on the supplies you asked for.

13c No girl in Illinois has straw a thousand crabs before March. *N

14c The local head of state may snob us not to panic. *N

11e Marissa vaguely knows my guy because they went to school together.

10e Pierre should quickly eat her hut because it's made of chocolate.

15g The meanest gossips saw your warn when they came into the meeting. *V

14g My ailing aunt could use their bring to cheer her up when she's lonely. *V

BlockA2

3a Her nephew, who brings her the paper, will send you a subscription form.

4a Our neighbor, who seldom comes near us, may lend us some sugar.

8c The club, which was founded by Pilgrims, has creek me to be a good person. *N

5c My aunt, who I go to see yearly, will chest me drive her car. *N

2e Even if someone would listen, my sky would still be gray.

1e Once the donations were counted, their night was just beginning.

7g After the promise was broken, her torn turned into a dead end. *V

8g Because the inspectors went northward, your let has been empty for decades. *V

11a The naughty little lad has stuck her finger in the paint.

12a The new believers here may bring a snack to share.

15c The nun in charge of lunch can nut you in the closet if you don't behave. *N

16c Artistic German kids can guy their parents for their talent. *N

9e The secretary found your straw in the hayloft where it belonged.

12e Armand should not have closed their den without asking them first.

16g The nursing home would like her fail delivered in the morning. *V

13g Matilda Jones picked out my shut before I ate it. *V

Block B1

7a The rat, which we captured this morning, has torn a hole in the box.

6a The puppy, which Marcus adopted, may put nose marks on the window

1c The wolf, who is steadily howling, can league if you ask him nicely. *N

2c The fish, which Mom bought for my birthday, can pot up to ten feet. *N

5e In order to master the problem, their toad has to be trained to stay.

6e Since I'm not hosting the party, my clay should be stored for next year.

3g Before they invented the motor, your grow had to be washed by hand. *V

4g When one of us stopped the commotion, her taught was still running quietly. *V

13a No girl in Illinois has caught a thousand crabs before March.

14a The local head of state may warn us not to panic.

9c The shaggy crippled dog will gown to sit while in this class. *N

10c Miranda Hammersmith will hut the money on the supplies you asked for. *N

15e The meanest gossips saw your snob when they came into the meeting.

14e My ailing aunt could use their mood to cheer her up when she's lonely.

10g Pierre should quickly eat her spend because it's made of chocolate. *V

11g Marissa vaguely knows my thank because they went to school together. *V

<u>Block B2</u>

5a My aunt, who I go to see yearly, will let me drive her car.

8a The club, which was founded by Pilgrims, has taught me to be a good person.

3c Her nephew, who brings her the paper, will wife you a subscription form. *N

4c Our neighbor, who seldom comes near us, may toad us some sugar. *N

7e After the promise was broken, her path turned into a dead end.

8e Because the inspectors went northward, your chest has been empty for decades.

1g Once the donations were counted, their sit was just beginning. *V

2g	Even if someone would listen, my put would still be gray.	*V
15a	The nun in charge of lunch can shut you in the closet if you don't behave.	
16a	Artistic German kids can thank their parents for their talent.	
11c	My absent-minded niece has den her finger in the paint.	*N
12c	The new believers here may mood a snack to share.	*N
16e	The nursing home would like her glass delivered in the morning.	
13e	Matilda Jones picked out my nut before I ate it.	
9g	The secretary found your caught in the hayloft where it belonged.	*V
12g	Armand should not have closed their stuck without asking them first.	*V

C. Experiment 2 Stimuli

Subject Group 1 Items

Block A1

1a	The wolf, who is steadily howling, will send you a subscription form.	
5a	My aunt, who I go to see yearly, can grow up to ten feet.	
6b	The puppy, which Marcus adopted, may shelf us some sugar.	*N
8b	The club, which was founded by Pilgrims, will girl me drive her car.	*N
3d	Before they invented the motor, her blood could be seen through the window.	
4d	When one of us stopped the commotion, her tribe could no longer continue.	
7f	After the promise was broken, your grow had the best bike in town.	*V
6f	Since I’m not hosting the party, your let has been lonely for decades.	*V
9a	The shaggy crippled dog has stuck her finger in the paint.	
10a	Miranda Hammersmith has caught a thousand crabs before March.	
13b	No girl in Illinois may kind a snack to share..	*N
14b	The local head of state can news their parents for their talent.	*N
11d	Marissa vaguely knows my flight to Kalamazoo, Michigan.	
10d	The singing group should hide my news about his former marriage.	
15f	The meanest gossips saw their bring of room humidifier.	*V
13f	Matilda Jones picked out their stuck without asking them first.	*V

BlockA2

3a	Her nephew, who brings her the paper, can sit if you ask him nicely.	
4a	Our neighbor, who seldom comes near us, may put nose marks on the window.	

7b	The rat, which we captured this morning, has blood me to be a good person.	*N
2b	The fish, which Mom bought for my birthday, has path a hole in the box.	*N
2d	Even if someone would listen, their league added up the total profits.	
1d	Once the donations were counted, my life would still be chaotic.	
5f	In order to master the problem, my send should be happy all winter.	*V
8f	Because the inspectors went northward, their lend has to be perfectly clean.	*V
11a	The naughty little lad may warn us not to panic.	
12a	The new believers here can shut you in the closet if you don't behave.	
15b	The nun in charge of lunch will food the money on the supplies they asked for.	*N
16b	Artistic German kids will glass to sit while in this class.	*N
9d	The secretary found her gown delivered in the morning.	
12d	Armand should not have closed her food before she sees it.	
16f	The nursing home would like your warn with all its ugly wrinkles.	*V
14f	My ailing friend could use your caught after he asked for directions.	*V

Block B1

6a	The puppy, which Marcus adopted, may lend us some sugar.	
7a	The rat, which we captured this morning, has taught me to be a good person.	
1b	The wolf, who is steadily howling, will clay you a subscription form.	*N
5b	My aunt, who I go to see yearly, can boy up to ten feet.	*N
8d	Because the inspectors went northward, their shelf has to be perfectly clean.	
6d	Since I’m not hosting the party, your girl has been lonely for decades.	
3f	Before they invented the motor, her taught could be seen through the window.	*V

4f	When one of us stopped the commotion, her torn could no longer continue.	*V
13a	No girl in Illinois may bring a snack to share.	
14a	The local head of state can thank their parents for their talent.	
9b	The shaggy crippled dog has desk her finger in the paint.	*N
12b	The new believers here can flight you in the closet if you don't behave.	*N
15d	The meanest gossips saw their kind of room humidifier.	
14d	My ailing friend could use your church after he asked for directions.	
10f	The singing group should hide my thank about his former marriage.	*V
11f	Marissa vaguely knows my shut to Kalamazoo, Michigan.	*V

<u>Block B2</u>

2a	The fish, which Mom bought for my birthday, has torn a hole in the box.	
8a	The club, which was founded by Pilgrims, will let me drive her car.	
3b	Her nephew, who brings her the paper, can night if you ask him nicely.	*N
4b	Our neighbor, who seldom comes near us, may life nose marks on the window.	*N
7d	After the promise was broken, your boy had the best bike in town.	
5d	In order to master the problem, my wife should be happy all winter.	
1f	Once the donations were counted, my put would still be chaotic.	*V
2f	Even if someone would listen, their sit added up the total profits.	*V
15a	The nun in charge of lunch will spend the money on the supplies they asked for.	
16a	Artistic German kids will fail to sit while in this class.	
11b	The naughty little lad may throat us not to panic.	*N
10b	Miranda Hammersmith has church a thousand crabs before March.	*N
16d	The nursing home would like your throat with all its ugly wrinkles.	

13d Matilda Jones picked out their desk without asking them first.

9f The secretary found her fail delivered in the morning. *V

12f Armand should not have closed her spend before she sees it. *V

Subject Group 2 Items

Block A1

1a The wolf, who is steadily howling, can sit if you ask him nicely.

2a The fish, which Mom bought for my birthday, can grow up to ten feet.

7c The rat, which we captured this morning, has tribe a hole in the box. *N

6c The puppy, which Marcus adopted, may sky nose marks on the window *N

3e Before they invented the motor, your pot had to be washed by hand.

4e When one of us stopped the commotion, her creek was still running quietly.

5g In order to master the problem, their lend has to be trained to stay. *V

6g Since I'm not hosting the party, my send should be stored for next year. *V

9a The shaggy crippled dog will fail to learn while in this class.

10a Miranda Hammersmith will spend the money on the supplies you asked for.

13c No girl in Illinois has straw a thousand crabs before March. *N

14c The local head of state may snob us not to panic. *N

11e Marissa vaguely knows my guy because they went to school together.

10e Pierre should quickly eat her hut because it's made of chocolate.

15g The meanest gossips saw your warn when they came into the meeting. *V

14g My ailing aunt could use their bring to cheer her up when she's lonely. *V

BlockA2

3a	Her nephew, who brings her the paper, will send you a subscription form.	
4a	Our neighbor, who seldom comes near us, may lend us some sugar.	
8c	The club, which was founded by Pilgrims, has creek me to be a good person.	*N
5c	My aunt, who I go to see yearly, will chest me drive her car.	*N
2e	Even if someone would listen, my sky would still be gray.	
1e	Once the donations were counted, their night was just beginning.	
7g	After the promise was broken, her torn turned into a dead end.	*V
8g	Because the inspectors went northward, your let has been empty for decades.	*V
11a	The naughty little lad has stuck her finger in the paint.	
12a	The new believers here may bring a snack to share.	
15c	The nun in charge of lunch can nut you in the closet if you don't behave.	*N
16c	Artistic German kids can guy their parents for their talent.	*N
9e	The secretary found your straw in the hayloft where it belonged.	
12e	Armand should not have closed their den without asking them first.	
16g	The nursing home would like her fail delivered in the morning.	*V
13g	Matilda Jones picked out my shut before I ate it.	*V

Block B1

7a	The rat, which we captured this morning, has torn a hole in the box.	
6a	The puppy, which Marcus adopted, may put nose marks on the window	
1c	The wolf, who is steadily howling, can league if you ask him nicely.	*N
2c	The fish, which Mom bought for my birthday, can pot up to ten feet.	*N

5e	In order to master the problem, their toad has to be trained to stay.	
6e	Since I'm not hosting the party, my clay should be stored for next year.	
3g	Before they invented the motor, your grow had to be washed by hand.	*V
4g	When one of us stopped the commotion, her taught was still running quietly.	*V
13a	No girl in Illinois has caught a thousand crabs before March.	
14a	The local head of state may warn us not to panic.	
9c	The shaggy crippled dog will gown to sit while in this class.	*N
10c	Miranda Hammersmith will hut the money on the supplies you asked for.	*N
15e	The meanest gossips saw your snob when they came into the meeting.	
14e	My ailing aunt could use their mood to cheer her up when she's lonely.	
10g	Pierre should quickly eat her spend because it's made of chocolate.	*V
11g	Marissa vaguely knows my thank because they went to school together.	*V

<u>Block B2</u>

5a	My aunt, who I go to see yearly, will let me drive her car.	
8a	The club, which was founded by Pilgrims, has taught me to be a good person.	
3c	Her nephew, who brings her the paper, will wife you a subscription form.	*N
4c	Our neighbor, who seldom comes near us, may toad us some sugar.	*N
7e	After the promise was broken, her path turned into a dead end.	
8e	Because the inspectors went northward, your chest has been empty for decades.	
1g	Once the donations were counted, their sit was just beginning.	*V
2g	Even if someone would listen, my put would still be gray.	*V

15a	The nun in charge of lunch can shut you in the closet if you don't behave.	
16a	Artistic German kids can thank their parents for their talent.	
11c	My absent-minded niece has den her finger in the paint.	*N
12c	The new believers here may mood a snack to share.	*N
16e	The nursing home would like her glass delivered in the morning.	
13e	Matilda Jones picked out my nut before I ate it.	
9g	The secretary found your caught in the hayloft where it belonged.	*V
12g	Armand should not have closed their stuck without asking them first.	*V

D. Experiment 3 Materials (Surveys 1 – 3)

Survey 1

Please choose the sentence from each pair that sounds more natural to you. Put an 'x' on the line next to your choice for "more natural."

	More natural?
1. The wolf, who is steadily howling, can sit if you ask him nicely.	___
1. The wolf, who is steadily howling, will send you a subscription form.	___
2. In order to master the problem, my wife should be happy all winter.	___
2. In order to master the problem, their shelf has to be perfectly clean.	___
3. The fish, which Mom bought for my birthday, can grow up to ten feet.	___
3. The fish, which Mom bought for my birthday, has torn a hole in the box.	___
4. Our neighbor, who seldom comes near us, may lend us some sugar.	___
4. Our neighbor, who seldom comes near us, may put nose marks on the window.	___
5. Artistic German kids can thank their parents for their talent.	___
5. Artistic German kids will spend the money on the supplies you asked for.	___
6. The meanest gossips saw their kind of room humidifier.	___
6. The meanest gossips saw your throat with all its ugly wrinkles.	___
7. My aunt, who I go to see yearly, will let me drive her car.	___
7. My aunt, who I go to see yearly, can grow up to ten feet.	___
8. Even if someone would listen, their night was just beginning.	___
8. Even if someone would listen, my life would still be chaotic.	___
9. Before they invented the motor, her blood could be seen through the window.	___
9. Before they invented the motor, your boy had the best bike in town.	___
10. The nursing home would like your throat with all its ugly wrinkles.	___
10. The nursing home would like her gown delivered in the morning.	___
11. The puppy, which Marcus adopted, may put nose marks on the window.	___
11. The puppy, which Marcus adopted, may lend us some sugar.	___
12. Since I'm not hosting the party, your girl has been lonely for decades.	___
12. Since I'm not hosting the party, my wife should be happy all winter.	___

13. The local head of state may warn us not to panic. ___
13. The local head of state can thank their parents for their talent. ___

14. After the promise was broken, your boy had the best bike in town. ___
14. After the promise was broken, her tribe could no longer continue. ___

15. The shaggy crippled dog will fail to sit while in this class. ___
15. The shaggy crippled dog may bring a snack to share. ___

16. My ailing friend could use your church after he asked for directions. ___
16. My ailing friend could use their kind of room humidifier. ___

17. Marissa vaguely knows my flight to Kalamazoo, Michigan. ___
17. Marissa vaguely knows my news about his former marriage. ___

18. Miranda Hammersmith will spend the money on the supplies you asked for. ___
18. Miranda Hammersmith has caught a thousand crabs before March. ___

19. The naughty little lad has stuck her finger in the paint. ___
19. The naughty little lad may warn us not to panic. ___

20. No girl in Illinois has caught a thousand crabs before March. ___
20. No girl in Illinois can shut you in the closet if you don't behave. ___

21. Her nephew, who brings her the paper, will send you a subscription form. ___
21. Her nephew, who brings her the paper, can sit if you ask him nicely. ___

22. Armand should not have closed her food before she sees it. ___
22. Armand should not have closed their desk without asking them first. ___

23. The rat, which we captured this morning, has torn a hole in the box. ___
23. The rat, which we captured this morning, has taught me to be a good person. ___

24. Matilda Jones picked out their desk without asking them first. ___
24. Matilda Jones picked out my flight to Kalamazoo, Michigan. ___

25. The nun in charge of lunch can shut you in the closet if you don't behave. ___
25. The nun in charge of lunch will fail to sit while in this class. ___

26. The new believer here has stuck her finger in the paint. ___
26. The new believer here may bring a snack to share. ___

27. Once the donations were counted, my life would still be chaotic. ___
27. Once the donations were counted, their league added up the total profits. ___

28. The club, which was founded by Pilgrims, has taught me to be a good person. ___
28. The club, which was founded by Pilgrims, will let me drive her car. ___

29. When one of us stopped the commotion, her tribe could no longer continue. ___
29. When one of us stopped the commotion, her blood could be seen through the window.___

30. Because the inspectors went northward, their shelf has to be perfectly clean. ___
30. Because the inspectors went northward, your girl has been lonely for decades. ___

31. The secretary found her gown delivered in the morning. ___
31. The secretary found your church after he asked for directions. ___

32. The singing group should hide my news about his former marriage. ___
32. The singing group should hide her food before she sees it. ___

Survey 2 version 1

Please rate the following sentences on a scale of 1 to 7:

1……….….2………..….3………..….4…………....5……………6……………7
least natural most natural

Sentence: Rating:

1. The wolf, who is steadily howling, will send you a subscription form. ___

2. The fish, which Mom bought for my birthday, has torn a hole in the box. ___

3. Her nephew, who brings her the paper, can sit if you ask him nicely. ___

4. When one of us stopped the commotion, her blood could be seen through the window.___

5. In order to master the problem, their shelf has to be perfectly clean. ___

6. Our neighbor, who seldom comes near us, may put nose marks on the window. ___

7. The singing group should hide her food before she sees it. ___

8. Marissa vaguely knows my news about his former marriage. ___

9. My aunt, who I go to see yearly, can grow up to ten feet. ___

10. The rat, which we captured this morning, has taught me to be a good person. ___

11. The puppy, which Marcus adopted, may lend us some sugar. ___

12. Even if someone would listen, my life would still be chaotic. ___

13. Before they invented the motor, your boy had the best bike in town. ___

14. Miranda Hammersmith has caught a thousand crabs before March. ___

15. The naughty little lad may warn us not to panic. ___

16. Matilda Jones picked out my flight to Kalamazoo, Michigan. ___

17. My ailing friend could use their kind of room humidifier. ___

18. The meanest gossips saw your throat with all its ugly wrinkles. ___

19. The new believer here has stuck her finger in the paint. ___

20. No girl in Illinois can shut you in the closet if you don't behave. ___

21. The local head of state can thank their parents for their talent. ___

22. The nun in charge of lunch will fail to sit while in this class. ___

23. Artistic German kids will spend money on the supplies you asked for. ___

24. Once the donations were counted, their league added up the total profits. ___

25. Since I'm not hosting the party, my wife should be happy all winter. ___

26. After the promise was broken, her tribe could no longer continue. ___

27. Because the inspectors went northward, your girl has been lonely for decades. ___

28. The club, which was founded by Pilgrims, will let me drive her car. ___

29. The shaggy crippled dog can bring a snack to share. ___

30. The secretary found your church after he asked for directions. ___

31. Armand should not have closed their desk without asking them first. ___

32. The nursing home would like her gown delivered in the morning. ___

Survey 2 version 2

Please rate the following sentences on a scale of 1 to 7:

1…………..2………..….3………..….4………….....5……………6……………7
least natural most natural

Sentence: Rating:

1. The wolf, who is steadily howling, can sit if you ask him nicely. ___
2. In order to master the problem, my wife should be happy all winter. ___
3. Since I'm not hosting the party, your girl has been lonely for decades. ___
4. The fish, which Mom bought for my birthday, can grow up to ten feet. ___
5. Her nephew, who brings her the paper, will send you a subscription form. ___
6. Our neighbor, who seldom comes near us, may lend us some sugar. ___
7. The meanest gossips saw their kind of room humidifier. ___
8. The nursing home would like your throat with all its ugly wrinkles. ___
9. My aunt, who I go to see yearly, will let me drive her car. ___
10. Even if someone would listen, their night was just beginning. ___
11. Before they invented the motor, her blood could be seen through the window. ___
12. The rat, which we captured this morning, has torn a hole in the box. ___
13. The puppy, which Marcus adopted, may put nose marks on the window. ___
14. The club, which was founded by Pilgrims, has taught me to be a good person. ___
15. The shaggy crippled dog will fail to sit while in this class. ___
16. Miranda Hammersmith will spend the money on the supplies you asked for. ___
17. The naughty little lad has stuck her finger in the paint. ___
18. The new believers here may bring a snack to share. ___

19. No girl in Illinois has caught a thousand crabs before March. ___

20. The local head of state may warn us not to panic. ___

21. Armand should not have closed her food before she sees it. ___

22. Matilda Jones picked out their desk without asking them first. ___

23. My ailing friend could use your church after he asked for directions. ___

24. The nun in charge of lunch can shut you in the closet if you don't behave. ___

25. Artistic German kids can thank their parents for their talent. ___

26. Once the donations were counted, my life would still be chaotic. ___

27. When one of us stopped the commotion, her tribe could no longer continue. ___

28. After the promise was broken, your boy had the best bike in town. ___

29. Because the inspectors went northward, their shelf has to be perfectly clean. ___

30. The secretary found her gown delivered in the morning. ___

31. The singing group should hide my news about his former marriage. ___

32. Marissa vaguely knows my flight to Kalamazoo. ___

Survey 3 version 1

In the following survey, you will be asked to rate sentences on a scale of 1 to 7.

1………..…2………..….3………..….4…………....5……………6……………7
least natural most natural

First, please rate the following examples: Rating:

1. The boy will kid a ball to his dog. ___

2. The mouse, who won the election, will eat our housecat. ___

Now please rate the following sentences on a scale of 1 to 7:

1……….….2………..….3………..….4…………....5……………6……………7
least natural most natural

Sentence: Rating:

[Word salad]

1. Fluff pumpkin eat Max hat gum. ___

2. Soon a fringe bite dancer television. ___

3. Always smoked queen Lucy waitress. ___

4. Clean has rocking chair monster very. ___

5. Landfill 8-year-old girl buried much cookie. ___

6. Two trunk children woman thought. ___

[Colorless green]

1. Heaping girls should wander directly through the ocean. ___

2. Walking fish may want to breathe odorless perfume. ___

3. Unrelated twins will pay quickly for free money. ___

4. The hideous beauty queens screamed quietly for paint. ___

5. Compassionate executioners deliver charity to the rich. ___

6. The notorious nobody snored sleeplessly through the day. ___

[Perfect]

1. The author of the best-selling novel will sign autographs for the crowd. ___

2. The dog fetched the newspaper and Marty gave him a bone. ___

3. Every pilot landed his airplane safely on the runway. ___

4. The hairdresser will cut and style my hair for the big party. ___

5. Doctors were confident they had caught the disease early enough to prevent it from spreading. ___

6. Scientists are working to build the world's most powerful laser. ___

[Experiment 2 grammatical]

1. The wolf, who is steadily howling, will send you a subscription form. ___

2. The fish, which Mom bought for my birthday, has torn a hole in the box. ___

3. Her nephew, who brings her the paper, can sit if you ask him nicely. ___

4. Our neighbor, who seldom comes near us, may put nose marks on the window. ___

5. My aunt, who I go to see yearly, can grow up to ten feet. ___

6. The rat, which we captured this morning, has taught me to be a good person. ___

7. The puppy, which Marcus adopted, may lend us some sugar. ___

8. The club, which was founded by Pilgrims, will let me drive her car. ___

9. The shaggy crippled dog has stuck her finger in the paint. ___

10. Miranda Hammersmith has caught a thousand crabs before March. ___

11. The naughty little lad may warn us not to panic. ___

12. The new believers here may bring a snack to share. ___

13. No girl in Illinois can shut you in the closet if you don’t behave. ___

14. The local head of state can thank their parents for their talent. ___

15. The nun in charge of lunch will fail to sit while in this class. ___

16. Artistic German kids will spend money on the supplies you asked for. ___

[Experiment 1 ungrammatical]

17. Once the donations were counted, their sit added up the total profits. ___

18. Even if someone would listen, my put would still be chaotic. ___

19. Before they invented the motor, your grow had the best bike in town. ___

20. When one of us stopped the commotion, her taught could be seen through the window.

21. In order to master the problem, their lend has to be perfectly clean. ___

22. Since I'm not hosting the party, my send should be happy all winter. ___

23. After the promise was broken, her torn could no longer continue. ___

24. Because the inspectors went northward, your let has been lonely for decades. ___

25. The secretary found your caught after he asked for directions. ___

26. The singing group should her spend before she sees it. ___

27. Marissa vaguely knows my thank about his former marriage. ___

28. Armand should not have closed their stuck without asking them first. ___

29. Matilda Jones picked out my shut to Kalamazoo, Michigan. ___

30. My ailing friend could their bring of room humidifier ___

31. The meanest gossips your warn with all its ugly wrinkles. ___

32. The nursing home would like her fail delivered in the morning. ___

Survey 3 version 2

In the following survey, you will be asked to rate sentences on a scale of 1 to 7.

1………..…2………..….3………..….4…………....5……………6……………7
least natural most natural

First, please rate the following examples: Rating:

1. The boy will kid a ball to his dog. ___

2. The mouse, who won the election, will eat our housecat. ___

Now please rate the following sentences on a scale of 1 to 7:

1………..….2………..….3………..….4…………....5……………6……………7
least natural most natural

Sentence: Rating:

[Word salad]

1. Fluff pumpkin eat Max hat gum. ___

2. Soon a fringe bite dancer television. ___

3. Always smoked queen Lucy waitress. ___

4. Clean has rocking chair monster very. ___

5. Landfill 8-year-old girl buried much cookie. ___

6. Two trunk children woman thought. ___

[Colorless green]

1. Heaping girls should wander directly through the ocean. ___

2. Walking fish may want to breathe odorless perfume. ___

3. Unrelated twins will pay quickly for free money. ___

4. The hideous beauty queens screamed quietly for paint. ___

5. Compassionate executioners deliver charity to the rich. ___

6. The notorious nobody snored sleeplessly through the day. ___

[Perfect]

1. The author of the best-selling novel will sign autographs for the crowd. ___

2. The dog fetched the newspaper and Marty gave him a bone. ___

3. Every pilot landed his airplane safely on the runway. ___

4. The hairdresser will cut and style my hair for the big party. ___

5. Doctors were confident they had caught the disease early enough to prevent it from spreading. ___

6. Scientists are working to build the world's most powerful laser. ___

[Experiment 2 grammatical]

1. The wolf, who is steadily howling, will send you a subscription form. ___

2. The fish, which Mom bought for my birthday, has torn a hole in the box. ___

3. Her nephew, who brings her the paper, can sit if you ask him nicely. ___

4. Our neighbor, who seldom comes near us, may put nose marks on the window. ___

5. My aunt, who I go to see yearly, can grow up to ten feet. ___

6. The rat, which we captured this morning, has taught me to be a good person. ___

7. The puppy, which Marcus adopted, may lend us some sugar. ___

8. The club, which was founded by Pilgrims, will let me drive her car. ___

9. The shaggy crippled dog has stuck her finger in the paint. ___

10. Miranda Hammersmith has caught a thousand crabs before March. ___

11. The naughty little lad may warn us not to panic. ___

12. The new believers here may bring a snack to share. ___

13. No girl in Illinois can shut you in the closet if you don’t behave. ___

14. The local head of state can thank their parents for their talent. ___

15. The nun in charge of lunch will fail to sit while in this class. ___

16. Artistic German kids will spend money on the supplies you asked for. ___

17. Once the donations were counted, my life would still be chaotic. ___

18. Even if someone would listen, their night was just beginning. ___

19. Before they invented the motor, her blood could be seen through the window. ___

20. When one of us stopped the commotion, her tribe could no longer continue. ___

21. In order to master the problem, my wife should be happy all winter. ___

22. Since I'm not hosting the party, your girl has been lonely for decades. ___

23. After the promise was broken, your boy had the best bike in town. ___

24. Because the inspectors went northward, their shelf has to be perfectly clean. ___

25. The secretary found her gown delivered in the morning. ___

26. The singing group should hide my news about his former marriage. ___

27. Marissa vaguely knows my flight to Kalamazoo. ___

28. Armand should not have closed her food before she sees it. ___

29. Matilda Jones picked out their desk without asking them first. ___

30. My ailing friend could use your church after he asked for directions. ___

31. The meanest gossips saw their kind of room humidifier. ___

32. The nursing home would like your throat with all its ugly wrinkles. ___

[Experiment 1 ungrammatical]

1. The wolf, who is steadily howling, can night if you ask him nicely. ___

2. The fish, which Mom bought for my birthday, can boy up to ten feet. ___

3. Her nephew, who brings her the paper, will clay you a subscription form. ___

4. Our neighbor, who seldom comes near us, may shelf us some sugar. ___

5. My aunt, who I go to see yearly, will girl me drive her car. ___

6. The rat, which we captured this morning, has path a hole in the box. ___

7. The puppy, which Marcus adopted, may life nose marks on the window. ___

8. The club, which was founded by Pilgrims, has blood me to be a good person. ___

9. The shaggy crippled dog will glass to sit while in this class. ___

10. Miranda Hammersmith will food the money on the supplies you asked for. ___

11. The naughty little lad has desk her finger in the paint. ___

12. The new believers here may kind a snack to share. ___

13. No girl in Illinois has church a thousand crabs before March. ___

14. The local head of state may throat us not to panic. ___

15. The nun in charge of lunch can nut you in the closet if you don't behave. ___

16. Artistic German kids can news their parents for their talent. ___

17. Once the donations were counted, their sit added up the total profits. ___

18. Even if someone would listen, my put would still be chaotic. ___

19. Before they invented the motor, your grow had the best bike in town. ___

20. When one of us stopped the commotion, her taught could be seen through the window. ___

21. In order to master the problem, their lend has to be perfectly clean. ___

22. Since I'm not hosting the party, my send should be happy all winter. ___

23. After the promise was broken, her torn could no longer continue. ___

24. Because the inspectors went northward, your let has been lonely for decades. ___

25. The secretary found your caught after he asked for directions. ___

26. The singing group should her spend before she sees it. ___

27. Marissa vaguely knows my thank about his former marriage. ___

28. Armand should not have closed their stuck without asking them first. ___

29. Matilda Jones picked out my shut to Kalamazoo, Michigan. ___

30. My ailing friend could their bring of room humidifier ___

31. The meanest gossips saw your warn with all its ugly wrinkles. ___

32. The nursing home would like her fail delivered in the morning. ___

E. Experiment 4 Stimuli

<u>Item Set 1</u>

Familiarization 1
her keb - my zav

Test 1
keb as noun set to random
zav as verb

1a	After the morning song, my keb sat on the table.	N
3h	The fish that she bought for our house can zav a kiss to his friend.	*N

Familiarization 2
her keb - my zav

Test 2
keb as verb set to random
zav as noun

3f	The wolf, who is awfully mean, will keb if you ask him nicely.	*N
1c	Before we play the game, her zav should be all clean.	N

Familiarization 3
can pell - will dak

Test 3
pell as verb
dak as noun

3a	His aunt, who visits us often, will pell a slice of cake.	V
1h	Because the swing was broken, her dak lay on the ground.	*V

Familiarization 4
can pell - will dak

Test 4
pell as noun
dak as verb

1f	Under the shiny lamp, my pell walked back and forth.	*V
3c	Our puppy, which Marcus found, can dak you a new book.	V

<u>Item Set 2</u>

Familiarization 1
my keb - her zav
Test 1
keb as noun
zav as verb
1b Under the shiny lamp, her keb walked back and forth.
N
3g Our puppy, which Marcus found, will zav you a new book.
*V

Familiarization 2
my keb - her zav

Test 2
keb as verb
zav as noun
3e My aunt, who visits us often, can keb a slice of cake.
*V
1d Because the swing was broken, my zav lay on the ground.
N

Familiarization 3
will pell - can dak

Test 3
pell as verb
dak as noun
3b The wolf, who is awfully mean, can pell if you ask him nicely.
V
1g Before we play the game, my dak should be all clean.
*N

Familiarization 4
will pell - can dak

Test 4
pell as noun
dak as verb

1e After the morning song, her pell sat on the table. *N
3d The fish that she bought for our house will dak a kiss to his friend. V

F. Experiment 5 Stimuli

Familiarization 1

1b My mommy baked the cookies for me and her keb. Then I gave her keb a cookie after I ate one myself. Under the shiny lamp, her keb walked back and forth. Her keb was very tired after walking under the lamp. We sang a song together so her keb could fall asleep.

3c We went to the store to buy a puppy that will dak. Our puppy, which Marcus found, will dak you a new book. He will dak around the room and he will dak all day long. Will he dak if Marcus is watching? We should ask the puppy if he will dak.

Test 1

my keb	N
my dak	*V
my sull	unfamiliar distractor

Familiarization 2

1c My friend Rebecca and my zav came over to my house to play. My zav was very dirty because it was in the sandbox yesterday. Before we play the game, my zav should be all clean. We washed my zav in the bathtub using lots of soap. Then we dried my zav with my own fluffy towel.

3d We went to the store to buy a fish that will dak. The fish that she bought for our house will dak a kiss to his friend. He will dak around the room and he will dak all day long. Will he dak if his friend is watching? We should ask the fish if he will dak.

Test 2

can zav	*N
can dak	V
can gud	unfamiliar distractor

Familiarization 3

1a We sang a song together so her keb would not feel lonely. Her keb was very tired after staying up late last night. After the morning song, her keb sat on the table. Then I gave her keb a cookie after I ate one myself. My mommy baked the cookies for me and her keb.

3b Every animal in the woods can pell anything they want. The wolf, who is awfully mean, can pell if you ask him nicely. He can pell behind the trees and he can pell next to the stream. Can he pell better than a bear? I don't know, we'll have to ask the wolf how well he can pell.

Test 3
will pell
will keb
will bok

Familiarization 4

1d My friend Elisa and my zav went to the park yesterday. My zav got very dirty from swinging on the swingset. Because the swing was broken, my zav lay on the ground. She helped my zav stand up after falling on the ground. Then she gave my zav a kiss on the forehead.

3a Everyone in his family can pell anything you want. His aunt, who visits us often, can pell a slice of cake. She can pell my pink pajamas and she can pell a blue balloon. Can she pell a purple kitten? I don't know, we'll have to ask his aunt what she can pell.
.

Test 4
her zav
her pell
her mof

<u>Item Set 2</u>

Familiarization 1

1b My mommy baked the cookies for me and her keb. Then I gave her keb a cookie after I ate one myself. Under the shiny lamp, her keb walked back and forth. Her keb was very tired after walking under the lamp. We sang a song together so her keb could fall asleep.

3c We went to the store to buy a puppy that will dak. Our puppy, which Marcus found, will dak you a new book. He will dak around the room and he will dak all day long. Will he dak if Marcus is watching? We should ask the puppy if he will dak.

Test 1
my keb N

my dak *V
my sull unfamiliar distractor

Familiarization 2

1c My friend Rebecca and my zav came over to my house to play. My zav was very dirty because it was in the sandbox yesterday. Before we play the game, my zav should be all clean. We washed my zav in the bathtub using lots of soap. Then we dried my zav with my own fluffy towel.

3d We went to the store to buy a fish that will dak. The fish that she bought for our house will dak a kiss to his friend. He will dak around the room and he will dak all day long. Will he dak if his friend is watching? We should ask the fish if he will dak.

Test 2
can zav *N
can dak V
can gud unfamiliar distractor

Familiarization 3

1a We sang a song together so her keb would not feel lonely. Her keb was very tired after staying up late last night. After the morning song, her keb sat on the table. Then I gave her keb a cookie after I ate one myself. My mommy baked the cookies for me and her keb.

3b Every animal in the woods can pell anything they want. The wolf, who is awfully mean, can pell if you ask him nicely. He can pell behind the trees and he can pell next to the stream. Can he pell better than a bear? I don't know, we'll have to ask the wolf how well he can pell.

Test 3
will pell
will keb
will bok

Familiarization 4

1d My friend Elisa and my zav went to the park yesterday. My zav got very dirty from swinging on the swingset. Because the swing was broken, my zav lay on the ground. She helped my zav stand up after falling on the ground. Then she gave my zav a kiss on the forehead.

3a Everyone in his family can pell anything you want. His aunt, who visits us often, can pell a slice of cake. She can pell my pink pajamas and she can pell a blue balloon. Can she pell a purple kitten? I don't know, we'll have to ask his aunt what she can pell.

Test 4
her zav
her pell
her mof

VITA

Jessica Peterson Hicks

4745 N. Malden St. Apt. 302
Chicago, IL 60640
Phone: (773) 506-1766
Email: jjpete@hotmail.com

Birthplace Pittsburgh, Pennsylvania

Education

2006 Ph.D. in Linguistics, Northwestern University
Specialization in Cognitive Science

1997 B.A., Linguistics, Rice University
Honors: *summa cum laude*, Phi Beta Kappa
George S. Cohen Full Scholarship

Conference presentations

2007 *The role of function words in infants' syntactic categorization of novel words.* Co-authors: Jeff Lidz and Jessica Maye. Paper selected for presentation at the annual conference of the Linguistics Society of America, Jan. 5, 2007.

2006 *On the role of function words in lexical access and syntactic processing*. Co-author: Jeff Lidz. Paper selected for presentation at the annual conference of the Linguistics Society of America, Jan. 3, 2006.

2004 *The role of function words in lexical access and syntactic processing.* Co-authors: Jeff Lidz and Janet Pierrehumbert. Presented at the 17th annual CUNY Sentence Processing Conference. March 25-27, 2004.

2003 *Measuring the unsaid: an empirical investigation of scalar implicature.* Presented at 8th International Conference on Pragmatics, Toronto. July 13-18, 2003.

Publications

2004 Lidz, J., McMahon, E., Syrett, K., Viau, J., Anggoro, F., Peterson Hicks, J., Sneed, E., Bunger, A., Flevaris, F., Graham, A., Grohne, K., Lee, Y. & Strid, E. *Quantifier raising in 4-year-olds.* Proceedings of 28th Boston University Conference on Language Development. MA: Cascadilla.

Professional experience

2004-Present Speech consultant, Versay Solutions LLC, Deerfield, IL. Responsible for developing PresentSpanish-language voice recognition systems for telephone system applications for major corporate clients.

Instructor, LING 224: Languages of Chicago, Northwestern University. Originated course concept and curriculum. Responsible for all aspects of the course as member of NU associate faculty.

2003 Researcher, "Quantifier raising in 4-year olds" Supervisor: Jeff Lidz. February – August.

Teaching assistant, Language and Prejudice (LING 221) Northwestern University. Instructor: Laura Dickey. Guest lecture: "Male-female communication/Language and gender"

Tutor, English as a Second Language Program, Northwestern University

2002 Instructor, Spoken English for Non-native Speakers (LING 380), Northwestern University. Lectured twice weekly in this course focused on English pronunciation for international students at Northwestern. Responsible for all aspects of course development and delivery.

Teaching assistant, Formal Analysis of Words and Syntax (LING 206), Northwestern University. Led/lectured during two hour-long discussion sections per week. Led review sessions, met with students during office hours. Responsible for grading/bookkeeping.

Teaching assistant, Language and Prejudice (LING 222), Northwestern University. Instructor: Laura Dickey. Led review sessions, met with students during office hours. Responsible for grading/bookkeeping.

2001 Research intern for Janet Pierrehumbert, Ph.D. Project: Quantifying children's vocabulary size.

2001 Tutor, English as a Second Language Program, Northwestern University
One-on-one English instruction/consultation for international students

1997-8 Director, Teacher Training Series, British Consulate, Monterrey, Mexico
Designed curriculum and led instructors at elementary and college prep schools in enhancement of English skills for teaching.

Private instructor of English for executives

Private instructor of TOEFL and SAT prep

1993-7 Private instructor of English as a Second Language, Rice University, Houston, TX

Awards and Honors

2004-5 Northwestern University Dissertation Year Fellowship

2001-3 Teaching Assistantships

2000-1 University Fellowship for Cognitive Science

Service

2003 Student coordinator, Linguistics Department Review/University Review

Graduate Student Representative to the Faculty, Linguistics Department

2001-4 Linguistics Department Colloquia Reception Committee

Languages

Spanish—fluent

French—fluent

Russian—working knowledge