Can prosodic cues and function words guide syntactic processing and acquisition ?

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Abstract

We tested the hypothesis that a rough syntactic analysis can be performed by relying on phrasal prosody and function words. We used jabberwocky sentences in which prosodic cues and function words were preserved, but all content words were replaced by non-words. French adults managed to perform an abstract word detection task (targets specified with their syntactic category) on these sentences. We interpret these results as showing that phrasal prosody and function words allow listeners to start building a syntactic structure of spoken nonsense sentences. Adults were able to use phonological phrase boundaries to delimit syntactic constituents, and function words to label these constituents. Implications for language acquisition are discussed.

1. Introduction

When acquiring their maternal language, infants have to learn its sound patterns (phonology), its words (lexicon) and its syntactic characteristics (the set of procedures that compute the meaning of a sentence from the meaning of its individual words). The acquisition of each of these components may be facilitated by assuming some knowledge in the others. For instance, since syntax defines the relationships between the words in a sentence, it has long been assumed that infants need to have access to words and their meanings in order to learn the syntax of their maternal language. Conversely, learning the meaning of words is a hard problem that would be facilitated by assuming that infants have access to at least some aspects of syntactic structure [2]. This leads to a "bootstrapping problem": the lexicon is needed to acquire syntax, and syntax is needed to construct the lexicon.

One way to resolve this bootstrapping problem is to look at what information is available from a bottom-up analysis of the speech signal. The phonological bootstrapping hypothesis [6] postulates that a purely phonological analysis of the speech signal may allow infants to acquire, among other things, some aspects of the syntax of their maternal language. In this research, we investigated the use of two different cues that are directly available in the speech signal: phrasal prosody (and more precisely phonological phrase boundaries) and function words.

1.1. Prosodic cues

Prosody refers to the melody of the language, and is characterized by variations of intonation and rhythm. Among the different prosodic units that have been described and integrated in a hierarchical structure [9], we investigated the role of phonological phrases: these are intermediate units, whose boundaries always correspond to syntactic boundaries [8]. They typically contain one or two content words, as well as the function words that are associated with them.

Previous research in French has shown that these prosodic cues can be useful for on-line adult syntactic processing [4, 5]. Millotte et al. used temporarily ambiguous sentences, exploiting the fact that two homophones can belong to different syntactic categories (e.g. a verb and an adjective). For instance, the word /mor/ can be either a verb, as in "[le petit chien] [**mord** la laisse]" - "[the little dog] [**bites** the leash]" (where brackets indicate phonological phrase boundaries), or an adjective, as in "[le petit chien **mort**] [sera enterré demain]" - "[the **dead** little dog] [will be buried tomorrow]". These two sentence beginnings are segmentally identical up to the ambiguous word, and differ only in their syntactic and prosodic structures: a phonological phrase boundary occurs before the ambiguous word when it is a verb, and after the ambiguous word when it is an adjective. We found that French adults were able to use this prosodic difference to distinguish between both sentence beginnings, and to correctly assign its syntactic category to the ambiguous word: for instance, in a completion task in which ambiguous sentences were cut just after the ambiguous word, French participants gave more adjective than verb responses to the ambiguous word when hearing adjective sentences (and vice-versa for verb sentences). Phonological phrase boundaries can thus guide the syntactic analysis of spoken sentences.

1.2. Function words

The second kind of information that we investigated is function words, namely articles, pronouns, auxiliaries... They play an important role in the syntactic analysis of sentences : for instance, some researchers have shown that young infants are able to use function words to correctly assign its syntactic category to the following word ([1] in French, [3] in German).

Furthermore, function words have interesting distributional properties that differentiate them from content words and make them easily learnable by infants : for instance, they are very frequent, and also have a tendency to be shorter and more reduced than content words [7, 10, 11]. In addition, function words occur preferentially at phonological phrase edges. These cues may be sufficient for infants to identify the function words of their maternal language.

1.3. Our working hypothesis

Prosodic boundaries and function words are directly available from the speech signal and can be processed very early by young infants. Our working hypothesis is that the joint use of prosodic information and function words may allow infants (and adults too) to build a skeleton of the syntactic structure of the sentences they hear. For instance, the sentence "the little boy is eating a cake" would be first represented with the following prosodic structure : "[xXxX] [xXx] [xX]" (where X and x represent strong and weak syllables respectively). The recognition of the function words at the beginning of the prosodic units would enrich this representation, as in "[the XxX] [is Xx] [a X]". Taken together, prosodic cues and function words may thus allow listeners to build the following initial syntactic structure, "[the XxX]$_{NP}$ [is Xx]$_{VP}$ [a X]$_{NP}$", in which syntactic boundaries are given by prosody (since phonological phrase boundaries correspond to syntactic boundaries), and group labels (noun phrase, verb phrase) are given by function words (for instance, a syntactic constituent that begins with an article would be considered as a noun phrase).

2. Method

To investigate this hypothesis, and to simulate language acquisition, we tested adults on jabberwocky sentences, where function words and prosodic information were preserved, but all content words were replaced by non-words.

We created two experimental conditions :

- a "with function word" condition : target words were directly preceded by a function word, as in "[une **bamoule**] [dri se froliter] [dagou]" (brackets indicate phonological phrase boundaries – the target word "bamoule" is a noun and it is preceded by an article – this sentence could be traduced in French by the following sentence, "[une **expo**] [doit se dérouler] [demain]" / "[an **exhibition**] [will take place] [tomorrow]").

On the other hand, we created a verb sentence, such as "[tu **bamoules**] [saman ti] [à mon ada]" (where the verb target "bamoules" is preceded by a pronoun – its French equivalent could be "[tu **travailles**] [souvent trop] [à mon avis]" / "[you often **work**] [too hard] [in my opinion]").

- a "without function word" condition : target words were not directly preceded by a function word. This condition was very close to Millotte et al.'s stimuli [4, 5] and was designed to test the role of phonological phrase boundaries in syntactic parsing. We used pairs of noun-verb sentences whose beginnings differed only in their prosodic and syntactic structures : for instance, we used the noun sentence "[une cramona **bamoule**] [camiche dabou]" ("[une formidable **expo**] [commence demain]" / "[a wonderful **exhibition**] [will begin tomorrow]") versus "[une cramona] [**bamoule** muche] [le mirtou]" ("[une étudiante] [**travaille** mieux] [le matin]" / "[a student] [**works** better] [in the morning]").

Fifty-two French adults performed an abstract word detection task on these sentences. Targets were specified with their syntactic category (infinitive form to detect a verb such as "bamouler" - "to bamoule" / "article + noun" to detect a noun such as "une bamoule" - "a bamoule"). Each sentence (noun and verb) was presented with both targets (noun and verb, balanced across participants). For instance, if a given participant was asked to detect a verb target, he had to respond to the verb sentence, and refrain from responding to the adjective sentence.

3. Results and Discussion

Participants' performance is shown in Figure 1.
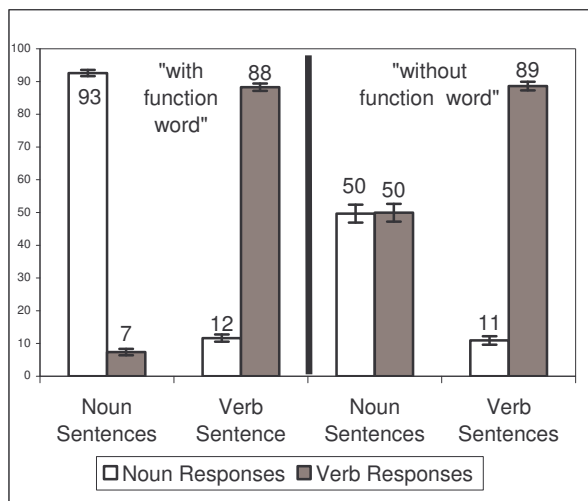
Figure 1 : Mean percentage of noun responses (in white) and verb responses (in grey) given to noun and verb sentences in each experimental condition. Error bars represent standard errors of the mean.

The results obtained in the "with function word" condition indicated that participants perfectly used the presence of function words immediately before the target words: in more than 90% of the cases, a non-word preceded by an article was interpreted as a noun, whereas it was considered to be a verb when preceded by a pronoun.

In the "without function word" condition, noun and verb sentences did not obtain the same responses pattern: participants managed to do the task when they were processing verb sentences, while they failed to do it when they were processing noun sentences. In fact, as noted above, there is an asymmetry between these sentences, relative to their first prosodic boundary position. In verb sentences, a phonological phrase boundary is placed just before the target word; participants had access to this prosodic information when they were processing the target word and integrating it into the syntactic structure. In this situation, they performed as well as in the "with function word" condition (around 90% of verb responses). To correctly assign its syntactic category to the target word, they had to use the information given by prosodic cues and function words. They probably interpreted phonological phrase boundaries as syntactic constituents boundaries ; the first syntactic unit was identify as a noun phrase because of the article "une" ; they hypothesized that the following constituent was most probably a verb phrase, and therefore interpreted the target word as a verb. They probably constructed the following syntactic structure, "[une cramona]$_{NP}$ [bamoule...]$_{VP}$", which supports our working hypothesis.

On the other hand, participants were at chance when responding to noun sentences in the "without clitic condition". In these sentences, a phonological phrase boundary was placed just after the target word : participants did not have access to enough disambiguating information to correctly interpret this target word. We have two explanations for this result: first, every syntactic boundary is not obligatorily marked by a prosodic boundary and participants were not able to interpret the absence of a prosodic boundary (whereas the presence of a prosodic boundary is clearly informative). On the other hand, participants may have interpreted the first syntactic constituent "[une cramona bamoule]" as a noun phrase and decided that the word following the article was a noun: in this case, the only remaining possibility was that the target word was an adjective (hence their uncertainty when they had to decide whether this sentence contained a verb or a noun target – the experiment never contained adjective targets).

4. Conclusions

This experiment indicates that function words and prosodic boundaries are very informative for adult syntactic processing : they allow them to start building a syntactic structure for spoken sentences (even if they do not understand the meaning of these sentences). French adults seem to use phonological phrase boundaries to identify syntactic constituents ; they used function words to label these syntactic constituents (noun phrase, verb phrase) and infer the syntactic category of some target words. Our hypothesis on syntactic acquisition thus seems to be plausible: in their second year of life, young infants do not yet know many content words; but they seem to have access to function words and prosodic boundaries. Thus they may be able to perform this kind of syntactic analysis, even before they have access to a full-fledged lexicon.

5. References

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