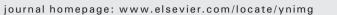
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# NeuroImage



## Time course and functional neuroanatomy of speech segmentation in adults

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### ABSTRACT

The present investigation was devoted to unraveling the time-course and brain regions involved in speech segmentation, which is one of the first processes necessary for learning a new language in adults and infants. A specific brain electrical pattern resembling the N400 language component was identified as an indicator of speech segmentation of candidate words. This N400 trace was clearly elicited after a short exposure to the words of the new language and showed a decrease in amplitude with longer exposure. Two brain regions were observed to be active during this process: the posterior superior temporal gyrus and the superior part of the ventral premotor cortex. We interpret these findings as evidence for the existence of an auditory-motor interface that is responsible for isolating possible candidate words when learning a new language in adults. © 2009 Elsevier Inc. All rights reserved.

#### Introduction

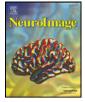
The present study was focused on understanding one of the initial processes in language learning: speech segmentation. The difficulty of the task lies in the lack of reliable acoustic cues that indicate where a word begins and ends. Thus, unlike the blank spaces that appear between printed words, the spoken acoustic signal could be considered, in many respects, continuous. Listeners, therefore, must parse the speech signal in order to start learning the new language. Notice that this initial process of isolating words is mandatory for subsequent language processes; for example, associating the possible lexical trace with a specific meaning.

To segment the auditory stream into words, the learner could exploit different acoustical cues such as allophonic variation, stress patterns, prosody, or/and distributional cues such as phonotactic regularities and transitional probabilities of syllable combinations (see for a review Jusczyk et al. (1999)). In relation to the distributional cues, several models have proposed the existence of a powerful statistical learning mechanism in order to explain speech segmentation (Brent, 1999). Supporting this idea, several experiments have shown that listeners are able to exploit the distributional properties of the input, regardless of whether it consists of syllables, tones or visual information (Fiser and Aslin, 2001; Saffran et al., 1999), and it likely proceeds in an incidental fashion (Saffran et al., 1997; Toro et al., 2005; Turk-Browne et al., 2005). Thus, statistical learning is understood as a domain-general mechanism that profits from the regularities of the environment to drive learning.

The computational implementation of this hypothesis has been successfully applied by connectionist models (Christiansen et al., 1998: Elman, 1990: for a different account see Brent, 1997). The underlying idea is that word boundaries are in locations where the transitional probabilities between two sounds are low. In other words, word boundaries can be inferred based on the fact that transitional probabilities are higher for word-internal than for word-external pairs of syllables. For instance, in the sentence "look, a balloon" the string "ba/lloon" is more likely to occur together across other sentences than the string "a/ba" as the latter string would not be heard in phrases such as "the balloon", "the red balloon", etc. In fact, it has been demonstrated in infants and adults that computing the transitional probabilities between syllables is sufficient for isolating new words that are embedded in an artificial continuous speech stream when no acoustical cues are available (Saffran et al., 1996a,b). Remarkably, this process is also accomplished by other animal species (Hauser et al., 2001; Toro and Trobalon, 2005), highlighting its generality.

Interestingly, an alternative computational proposal suggests that the formation of syllabic chunks might be the only process required to isolate possible words (Perruchet and Vinter, 1998). Accordingly to the authors, a chunk can be considered that brings together the elements that are at the attentional focus at a particular moment. In subsequent





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