available at www.sciencedirect.com

ScienceDirect

www.elsevier.com/locate/brainres

BRAIN RESEARCH

Research Report

Interaction of right- and left-edge prosodic boundaries in syntactic parsing

*Mikael Roll**, *Merle Horne*

Department of Linguistics and Phonetics, Lund University, Box 201, 22100 Lund, Sweden

ARTICLE INFO

Article history:
Accepted 1 June 2011
Available online 12 June 2011

Keywords:
P200
N100
Closure Positive Shift
Anterior negativity
Prosody
Syntax

ABSTRACT

This electrophysiological study investigated how right- and left-edge prosodic boundary tones interact in the processing of syntactic structure. Swedish sentences of the type 'Peter hit Larry(NP2) and Jason(NP3) fell/hard…' were used. A verb ('fell') requires a clause boundary between NP2 and NP3, whereas an adverb ('hard') implies continuation of the first clause, which incorporates NP3 as a coordinated object. The effects of right-edge prosody associated with NP2 and left-edge prosody associated with NP3 were tested. Results suggest interaction between prosodic right- and left-edge boundary cues both at the earliest stages of processing the left-edge boundary tone on NP3 and at the immediately following word category distinction. Right-edge boundary tones on NP2 yielded an early positive deflection (P200) and a later positivity (CPS). Left-edge tones on NP3 showed a P200 effect only if preceded by a right-edge boundary on NP2. In the absence of a prosodic right-edge boundary, left-edge tones instead yielded an early negativity (N100), suggesting that they were unexpected. At the following word category distinction point, adverbs, showing continuation of the first clause, produced an anterior negativity when preceded by both right- and left-edge prosodic boundaries. The negativity is thought to reflect detection of a syntactically incorrect word category. Syntactically un-preferred constructions with an adverb following NP3 received generally lower acceptability ratings and gave rise to a P600 effect in all conditions. Syntactically preferred constructions with verbs following NP3 showed a similar P600 only when not preceded by either right- or left-edge boundary tones.

1. Introduction

Humans are capable of performing a complex syntactic analysis of a stream of speech sometimes delivered at speeds of over six syllables per second (Levelt, 1989). This remarkable processing speed could be partly attributed to pre-activation of syntactic structures by prosodic cues (Roll et al., 2011). For example, NP2 and NP3 in the clause *Peter hit Larry*$_{NP2}$ *and Jason*$_{NP3}$… might constitute a coordinated object of the verb *hit*. A possible continuation would then be the adverb *hard*, i.e. *Peter hit Larry*$_{NP2}$ *and Jason*$_{NP3}$ *hard*. However, NP3 could also start a new main clause, hence being followed by a verb, e.g. *fell* in *Peter hit Larry*$_{NP2}$ *and Jason*$_{NP3}$ *fell*. A prosodic right-edge boundary on NP2 would signal the end of the first clause

* *Corresponding author*. Fax: +46 46 2223211.
E-mail addresses: mikael.roll@ling.lu.se (M. Roll), merle.horne@ling.lu.se (M. Horne).

0006-8993/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.brainres.2011.06.002

(Kjelgaard and Speer, 1999; Speer et al., 1996; Steinhauer et al., 1999), and could therefore prepare the listener for the new clause. In Swedish, a high left-edge boundary tone would further be used on NP3 to signal the beginning of the new main clause (Roll et al., 2009, 2011). We investigate how prosodic right-edge boundaries affect processing of following left-edge boundary tones, and how both prosodic boundaries interact in their function as cues for a new main clause structure, evidenced syntactically by a subsequent verb such as *fell* in *Peter hit Larry*$_{NP2}$ *and Jason*$_{NP3}$ *fell*. The aim of the study is to make a contribution to the work on adding a detailed timeline to accounts of prosody-syntax interaction such as the Dual Pathway Model (Friederici and Alter, 2004).

1.1. *Boundary tone processing*

The beginning of utterances is normally associated with more energy and higher pitch than the end because of physical conditions on exhalation (Gussenhoven, 2002). In Swedish, this tendency has been conventionalized into the use of a high boundary tone at the beginning (left edge) of main clauses (Roll et al., 2009, 2011) and a low boundary tone at the end (right edge) of clauses (Bruce, 1977).

Prosodic right-edge boundaries close a clause for further integration of words. In Event-Related Potential (ERP) studies, this process is reflected in a centroparietal 'closure positive shift' (CPS) (Bögels et al., 2010, in press; Kerkhofs et al., 2007; Männel and Friederici, 2009; Pannekamp et al., 2005; Pauker et al., in press; Steinhauer et al., 1999).

The high left-edge boundary tone has been seen to yield an early anterior positivity, interpreted as a P200 effect (Roll et al., 2009, 2011). The P200 is thought to originate mainly in the superior temporal and perhaps frontal cortex, (Papanicolaou et al., 1990), and has been argued to reflect classification of auditory stimuli as behaviorally relevant (Larrea et al., 1992) or even early allocation of attention (Näätänen, 1992). A possible interpretation is that the P200 reflects allocation of anticipatory attention to the main clause structure that the left-edge boundary tone is associated with. In line with this idea, main clauses without a left-edge boundary tone yielded a P600 effect in an embedded context (Roll et al., 2009, 2011). The main clause structure was evidenced by a word order difference between main clauses and subordinate clauses. The P600 is a posterior positivity peaking around 600 ms after structurally unexpected stimuli (Osterhout and Holcomb, 1992), possibly indexing difficulty in syntactic integration (Kaan et al., 2000). It thus seems that listeners need the tonal cue to be prepared for an embedded main clause word order. In a similar way, a high tone on Swedish word stems ('Accent 2') has been seen to cue a certain class of associated suffixes (Roll et al., 2010). The same ERP pattern is also observed in the processing of the tone-suffix relation: a frontocentral positivity (P200) for the high stem tone, and a P600 effect for "Accent 2 suffixes" in the absence of their cueing tone. P200 effects have also been found for left-edge boundaries in music (Knösche et al., 2005), as well as for sentence-initial accents in German (Heim and Alter, 2006). If the P200 reflects early allocation of attention driven by linguistically relevant tone changes, even right-edge boundary tones would be expected to elicit a P200 effect in addition to the CPS.

If a prosodic right-edge boundary indicates clause closure after NP2 in *Peter hit Larry*$_{NP2}$ *and Jason*$_{NP3}$…, then NP3 would be more likely to be the subject in a new main clause. Therefore, in Swedish, a left-edge boundary tone would be more expected on NP3 in the presence of a right-edge boundary tone on NP2. In Roll et al. (2009), left-edge boundary tones in embedded clauses did not yield any P200 effect if they were preceded by main clause verbs that did not permit embedded main clauses. It might thus be that the tone was not perceived as relevant if its cued structure was not permitted, and therefore, the tone did not increase main clause structure activation. Consequently, the P600 for a following embedded main clause structure was not significantly affected by the left-edge boundary tone in the context of a preceding adverse main clause verb. Similarly, in the present study, a right-edge boundary tone on NP2 could be expected to influence the P200 of a following high left-edge boundary tone on NP3.

1.2. *Prosody and syntactic disambiguation*

Prosodic cues can be thought to be capable of adjusting the degree of activation of syntactic structures during parsing. In the case of right-edge boundaries, the presence of prosodic cues seems to have greater effects on syntactic processing than the absence of prosodic cues (Bögels et al., in press; Steinhauer et al., 1999), as formulated in the Boundary Deletion Hypothesis (Steinhauer and Friederici, 2001). Thus, Pauker et al. (in press) showed that when NP2 was incorrectly preceded by a right-edge boundary (indicated with '||') in sentences such as *When a bear is approaching || the people*$_{NP2}$ *the dogs*$_{NP3}$ *come running*, NP3 produced a P600, showing syntactic integration difficulty. On the other hand, the lack of a prosodic boundary (Ø) in the corresponding *When a bear is approaching Ø the people*$_{NP2}$ *come running*, gave rise to a smaller P600. In the case of left-edge prosody, Roll et al.(2011) found the opposite relation to hold, i.e. the absence of a left-edge boundary tone gave rise to a P600 effect for embedded main clauses, whereas its presence did not affect processing of a competing subordinate clause structure. However, the lack of an effect of the presence of a left-edge boundary tone in the sentences processed in Roll et al. (2011) might have been due to an inherent syntactic preference leading to stronger activation for subordinate clause structure. This preference was reflected in higher acceptability ratings for subordinate clauses than for embedded main clauses.

The adverb *hard* following a "heavy," coordinated NP in sentences like *Peter hit Larry*$_{NP2}$ *and Jason*$_{NP3}$ *hard* is grammatically correct, but marked in Swedish (see e.g. Ross, 1967 on this type of construction). Conversely, the verb continuation cued by a left-edge boundary tone on NP3 in sentences like *Peter hit Larry*$_{NP2}$ *and Jason*$_{NP3}$ *fell* is not marked. Since there is no parsing preference that overrides its cued syntactic structure, the left-edge boundary tone could here be expected to conform to the Boundary Deletion Hypothesis, limiting activation to its associated main clause pattern. A right-edge boundary tone on NP2 in *Peter hit Larry*$_{NP2}$ *and Jason*$_{NP3}$… would increase activation of a verb continuation (*fell*) after NP3. If a left-edge boundary tone on NP3 confirms the beginning of a new main clause, an adverb might be perceived as grammatically incorrect, since Swedish is a strict "verb second" language, i.e. in main clauses, the verb