Journal of Neurolinguistics 42 (2017) 63–82

Contents lists available at ScienceDirect

Journal of Neurolinguistics

journal homepage: www.elsevier.com/locate/jneuroling

An ERP investigation of quantifier scope ambiguous sentences: Evidence for number in events

Veena D. Dwivedi [a, b, *], Raechelle M. Gibson [b, 1]

[a] Department of Applied Linguistics, Brock University, Niagara Region, 1812 Sir Isaac Brock Way, St. Catharines L2S 3A1 ON, Canada
[b] The Centre for Neuroscience, Brock University, Niagara Region, 1812 Sir Isaac Brock Way, St. Catharines L2S 3A1 ON, Canada

ARTICLE INFO

Article history:
Received 22 April 2016
Received in revised form 11 November 2016
Accepted 11 November 2016
Available online 6 December 2016

Keywords:
ERPs
Language
Semantic ambiguity
Quantifier
Number
P300

ABSTRACT

We used event related potentials (ERPs) in order to investigate how sentences, semantically ambiguous with respect to number, are understood. Although sentences such as (i) *Every kid climbed a tree* lack any syntactic or lexical ambiguity, two possible meanings are available, where either many trees or just one tree was climbed. Previous behavioural studies showed a plural preference, whereas ERP and behavioural experiments conducted in our lab have not. In this work, we further investigate sentences as in (i), called quantifier scope ambiguous sentences, and compare them to unambiguous sentences, (ii) *Every kid climbed the trees*. Participants read sentences presented in 1- and 2-word chunks, and judged, at the target word *tree(s)*, whether 1 or 2 words appeared on the computer screen (Berent *et al.*, 2005). Previously, interference effects resulted for judgments that 1 word was on the screen when it was marked plural (e.g., *trees*) versus singular (e.g., *tree*). Interestingly, Patson and Warren (2010) also showed that this was the case for judgments made for singular words, e.g., *tree,* in quantifier ambiguous sentences, confirming the plural preference. The current ERP study did not replicate their behavioural findings. Difficulty for "1" responses was not observed for *trees* in (ii) nor was it observed for *tree* in quantifier scope sentences (i). Instead, a P300 effect was found at the target word *tree(s)*, where amplitudes differed depending on congruency in number interpretation for subjects and direct objects. Results are discussed in terms of heuristic first sentence processing mechanisms, and relevant features of event knowledge.

1. Introduction

All human languages have a way of distinguishing between individuals and sets of individuals. As such, understanding how people comprehend the singular-plural distinction is a crucial facet in explaining our effortless capacity for language. This facile capacity is even more remarkable given that some sentences are ambiguous with respect to number interpretation.

For example, quantifier scope ambiguous sentences such as *Every kid climbed a tree* are ambiguous in terms of numerical interpretation—either one or several trees are inferred (see Fig. 1). Despite this ambiguity, these sentences are often interpreted the same way across readers/listeners, where the plural interpretation is preferred. The preference in interpretation

* Corresponding author. Department of Applied Linguistics, Brock University, Niagara Region, 1812 Sir Isaac Brock Way, St. Catharines L2S 3A1 ON, Canada.
E-mail address: vdwivedi@brocku.ca (V.D. Dwivedi).
[1] Raechelle M. Gibson is now at the Department of Psychology and The Brain and Mind Institute, Western University, London, ON, Canada, N6A 5B7.

http://dx.doi.org/10.1016/j.jneuroling.2016.11.006
0911-6044/

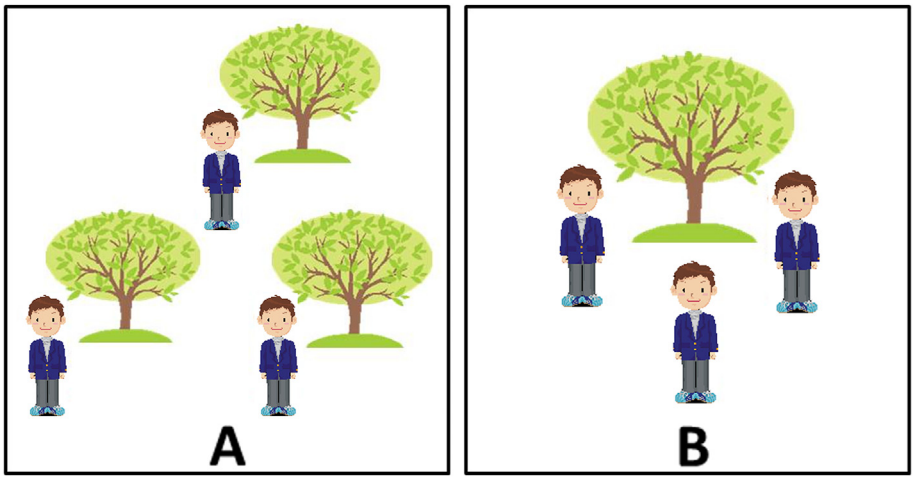

Fig. 1. *Possible interpretations of quantifier scope ambiguous sentences*. A graphical representation of the two possible interpretations of the quantifier scope ambiguous sentence, *Every kid climbed a tree*, according to plural (A) and singular interpretation (B).

has been accounted for via the preferred application of an abstract semantic rule, called quantifier ordering (May, 1985; Russell, 1905). A number of psycholinguistic investigations (Bott & Schlotterbeck, 2015; Filik, Paterson, & Liversedge, 2004; Kurtzman & MacDonald, 1993; Paterson, Filik, & Liversedge, 2008; Patson & Warren, 2010; Raffray & Pickering, 2010) have empirically found the plural preference[2] and have attributed this preference to the application of the abstract rule of quantifier ordering.

In a recent Event Related Potential (ERP) study, (Dwivedi, Phillips, Einagel, & Baum, 2010), as well as three behavioural experiments reported in Dwivedi (2013), we examined quantifier scope ambiguous sentences, such as *Every kid climbed a tree,* and did not find the plural preference as participants read. Measurements were taken at sentences such as *The tree was in the park*, or *The trees were in the park*, which followed quantifier scope sentences. Neither brain wave patterns, nor word-by-word reading time patterns, indicated an on-line preference for the plural interpretation, in any of the experiments. We claimed that quantifier scope ambiguous sentences are interpreted using "Heuristic first, algorithmic second" processing mechanisms. That is, in real-time, people do not use deep "algorithmic" semantic rules for sentence interpretation. Instead, they primarily use associative word-based heuristic strategies (cf. Kahneman, 2011). Our claim that quantifier scope ambiguous sentences are interpreted via heuristic strategies flies in the face of the majority of psycholinguistic studies examining these sentences (see above), which assume that the linguistic rule of quantifier ordering is primary in their comprehension.

In an attempt to reconcile our findings, we add to this debate by using an innovative method recently discussed in a behavioural study by Patson and Warren (2010). Briefly, as described below, their method allows for a direct measure at quantifier scope sentences, which is also sensitive to number judgments. We note that in our previous ERP work, (Dwivedi et al., 2010), we did not query participants about their number judgments, in order to avoid potential ERP artefacts (Kaan & Swaab, 2003). Presently, we extend Patson and Warren's (2010) methods, via ERP measurements, in order to potentially induce algorithmic processing of scope, which would result in a plural preference.

Patson and Warren (2010) examined the on-line interpretation of quantifier scope ambiguous sentences, such as *Each of the men carried a box*. In sentences of this type, the direct object *box* is interpreted as plural. In contrast, sentences using subjects beginning with *Together,* as in *Together the men carried a box,* result in a singular interpretation for the direct object *box*. Their study used self-paced reading methodology with a twist: words appeared on the screen in one-versus two-word chunks, and if a word was presented in blue font, participants had to judge how many words were on the screen. Participants did so by pressing either "1" or "2" on the keyboard. Following Berent, Pinker, Tzelgov, Bibi and Goldfarb (2005), Patson and Warren hypothesized that participants would be slower to press "1" when the word was plural (*e.g.*, *boxes*) versus when it was singular (*e.g.*, *box*). To this end, two plural control conditions were included: *Each of the men carried some boxes* and *Together the men carried some boxes.* Results confirmed their hypothesis: response times for pressing "1" to *boxes* were indeed longer than those for pressing "1" to *box*. These results show that the cognitive act of counting and pressing the "1" button can be interfered with by plural number marking at the direct object *boxes*. Furthermore, they found that *box* in the (quantifier scope) *Each* condition also resulted in longer "1" button pressing times. They concluded that this task is sensitive not only to plural interpretation due to overt morphology at the direct object, but also due to (covert) conceptual number interpretation—as a result of the quantified subject *Each*.

[2] For ease of exposition, we will refrain from using the terms surface scope reading, as consistent with the plural interpretation, and inverse scope reading, as consistent with the singular interpretation. Please see Dwivedi (2013), and references cited therein, for further discussion of quantifier scope theory.