Quantification, attention, and the P300 effect

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BACKGROUND INFORMATION

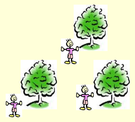
What can investigations in semantic ambiguity reveal about underlying language processing mechanisms?

- Examine Quantifier Scope Ambiguity
- *Every N1 Verbed a N2*

Two possible meanings; meaning determined by the order of interpretation of quantifiers (i.e. scope interpretation)

Every kid climbed a tree

Surface scope interpretation: **Inverse scope interpretation**:



Disambiguation of QSA sentences

•Relies on number interpretation

•Previous work, eg., Kurtzman and MacDonald (1993) showed that plural interpretation was preferred. However, Dwivedi (2013; see also Dwivedi et al., 2010) showed that sentences are processed using a Heuristic first, algorithmic second strategy, such that QSA is not computed at all. Instead, readers rely on lexical-pragmatic biases (i.e., heuristics) associated with sentences for interpretation.

•Perhaps findings differed because participants were paying less attention due to: lack of time; also no task on critical stimuli (cf Kaan & Swaab, 2003).

INTRODUCTION

•Build on recent work by Patson and Warren (2010) who conducted (dual task) self-paced reading study

•Participants responded to one- or two-word chunks to indicate whether one or two words were on the screen.

•RTs were longer for number judgments for single plural words (e.g., *crayons*) than for single singular words (e.g., *crayon*) in unambiguous sentences

- e.g. *The child* | *coloured* | *with the* | *crayon/crayons.*
  - ➢This finding supports that **morphological** plurality can interfere with number judgments (see also Berent et al., 2005)

What about conceptual plurality, as in Quantifier Scope Ambiguity?

(I) Each of the men carried a box.
(II) Together the men carried a box.

•(I) Ambiguous interpretation; preference for plural interpretation of "box" (due to distributive property of **Each**).

•(II) Unambiguous interpretation; one box.

•For **Each** sentences, RTs were longer for single singular words (e.g., ***box***) vs. **together** sentences (note that accuracy was at ceiling).

➢This finding supports that **conceptual plurality** can interfere with number judgments

PRESENT STUDY: Dual Task ERP Language

If 2^0 task of counting words is included in 1^0 task of reading QSA sentences, will this facilitate algorithmic computation?

Predictions

•Morphological and conceptual plurality will interfere with number judgments

•If 2^0 task and time make a difference, then participants will compute (algorithmic) scope. Responses to *Every kid climbed a tree* should differ empirically from *The kid climbed a tree* (no empirical difference predicted amongst other conditions)

•On the other hand, the addition of this task might *not* affect sentence processing strategy.

•Participants might process in shallow manner again, due to the presence of the quantifier *Every*. If so, less attention will be paid to *Every* sentences, leaving more resources available for 2^0 task of counting number of words on the screen (Donchin, 1981) for quantificational vs. non-quantificational sentences.

•Predict P300 effect, with amplitude difference between sentences containing quantifiers vs. those that do not; greater P300 amplitude for quantificational sentences.

METHOD

Object NP Type

Subjet Determiner Type	Indefinite (Ind)	Singular Definite (DefSg)	Definite Plural (DefPl)
Quantifier (+Q)	Every kid | climbed a | **tree** | in the | autumn.	Every kid | climbed the | **tree** | in the | autumn.	Every kid | climbed the | **trees** | in the | autumn.
No Quantifier (-Q)	The kid | climbed a | **tree** | in the | autumn.	The kid | climbed the | **tree** | in the | autumn.	The kid | climbed the | **trees** | in the | autumn.

Participants

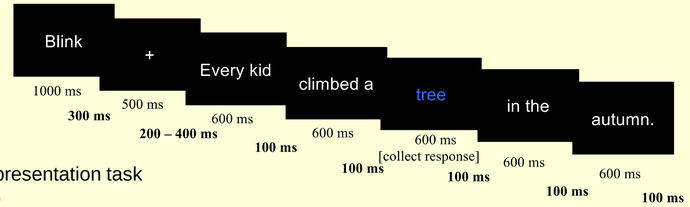
- 10 (7 female; mean age 19.40 years) right-handed native English speakers from Brock University
- No self-reported visual or neurological impairments

Materials

•156 target sentences with 300 filler sentences

•110 (~25%) filler sentences featured comprehension questions

•Stimuli separated into six lists so that each condition was equally represented and no item appeared in the same list more than once



Procedure

•Fixed pace, serial visual presentation task

•700 ms SOA (100 ms ISI)

•Variable ITI (500 to 1000 ms)

•Responses were collected at critical words marked with blue font

ERP Recording

•EEG was recorded from a 64 channel ActiveTwo BioSemi system, and re-referenced off-line to linked mastoid electrodes. Data were sampled at a rate of 512 Hz and digitized with a 24-bit analog-to-digital converter. All EEG analyses were performed with EMSE 5.5.1 (www.sourcesignal.com)

•EEG epochs were time-locked to the onset of each critical stimulus.

RESULTS

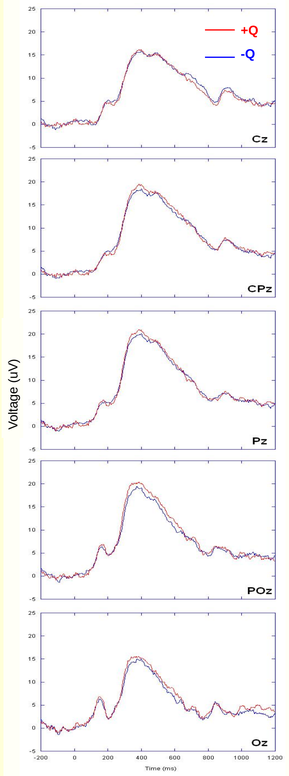


Figure 1. ERP waveforms for non-quantificational (-Q) vs. quantificational (Q) stimuli at midline electrode sites.

• **Compare non-quantificational vs. quantificational sentences**

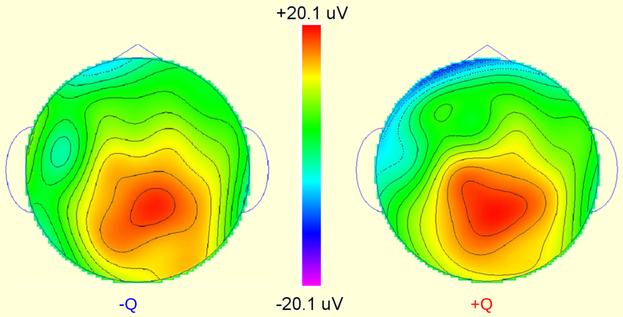
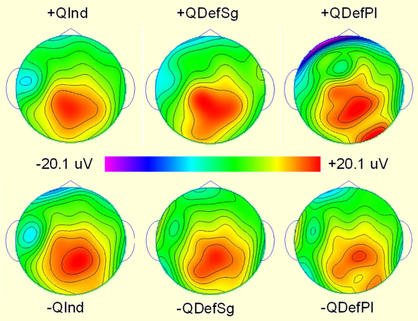


Figure 2. Topographic map of cortical activity for non-quantificational (-Q) and quantificational (+Q) stimuli at time window 300-500ms, across all electrodes.

• Examine parietal sites: CPz, Pz, POz in the typical P300 time window: 300-500ms (and by visual inspection; 500-700ms)

•Main effect of Quantifier $F(1,9) = 12.31$, $p = .007$; this effect is driven by the plural condition, see the topographic map in Figure 3.

RESULTS



• **Figure 3.** Topographic maps comparing cortical activity across all 6 critical conditions in 300-500 ms time window

•**Behavioural Accuracy Data:**

Type of Subject	Type of Object: Indefinite	Def. Singular	Def. Plural
+Q	81%	82%	80%
-Q	76%	82%	74%

p=.08

DISCUSSION

- We did not replicate the Patson and Warren (2010) self-paced reading results, i.e, we did not find a significant empirical difference between the +QInd condition (exhibiting QSA) vs. –QInd (unambiguous).
- Overall the +Q conditions patterned together—these evoked larger P3 amplitudes as compared to the –Q conditions.
- Thus, findings centre around modulation of attention in language processing: P3 effect.
- These findings dovetail nicely with recent proposal in Dwivedi (2013).
- Is it about probability of sentences starting with "Every" (Quantifier) vs. "The" (definite determiner)?
- No, due to careful experimental design, this was counterbalanced across critical items and fillers.
- Confirms Luck (1998) **"P3 amplitude can be used as a relatively pure measure of the availability of cognitive processing resources for accomplishing target perception and categorization**, " (p. 223).
- Interestingly, preliminary behavioural data (10ppts) show that –QDefPl was least accurate condition (i.e, precisely where ppts have fewest attentional resources to respond to target, responses were least accurate).
- Furthermore, trend showing that Plural conditions were less accurate than singular conditions.
- These findings highlight the importance of utilizing converging methodologies (e.g. self-paced reading, ERPs, offline rating tasks, etc.)

FUTURE STUDIES

- Include a context sentence prior to "*Every*" sentence: give the quantifier a range (c.f, "*Each of the..*").
- Perform self-paced reading study with ERP methods
- Examine norms associated with QSA: plural vs. singular interpretational biases (see also Dwivedi & Curtiss, 2013).

SELECTED REFERENCES

Berent, I., Pinker, S., Tzelgov, J., Bibi, U., & Goldfarb, L. (2005). Computation of semantic number from morphological information. *Journal of Memory and Language, 53,* 342-358. **Donchin, E.** (1981). Presidential Address, 1980: Surprise!...Surprise? *Psychophysiology, 18*(5), 493-513. **Donchin, E. & Coles, M.** (1988). Is the P300 component a manifestation of context updating? *Behavioral and Brain Sciences, 11*(3), 357-374. **Dwivedi, V.D.** (1996). Modality and discourse processing. In: Montrul, S., Kessler Robb, M. (Eds.), McGill Working Papers in Linguistics, 12. Dept of Ling, McGill University. Montreal, pp. 17-52. **Dwivedi, V.** (2011). *Interpreting scope ambiguity: Evidence of heuristic first, algorthmic second processing.* Manuscript submitted for publication. **Dwivedi, V., Phillips, N., Einagel, S., & Baum, S**. (2010). The neural underpinnings of linguistic ambiguity. *Brain Research, 1311*, 93-109. **Dwivedi, V. & Curtiss, K.** (2013). The computation of meaning via event knowledge and number. Poster presentation for the *20th Annual Meeting of the Cognitive Neuroscience Society*. San Francisco, USA. **Kurtzman, H., & Kutas, M., McCarthy, G., & Donchin, E.** (1977). Augmenting mental chronometry: The P300 as a measure of stimulus evaluation time. *Science, 197,* 792-795. **Luck, S. J.** (1998). Sources of dual-task interference: Evidence from human electrophysiology. *Psychological Science, 9*(3), 223-227. **MacDonald (1993).** Resolution of quantifier scope ambiguities. *Cognition, 48*, 243-279. **Tunstall, S.L.** (1998). The interpretation of quantifiers: Semantics and processing. Unpublished doctoral dissertation, University of Massachusetts, Amherst. **Patson, N. D., & Warren, T.** (2010). Evidence for distributivity effects in comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 36*, 782-789. **Polich, J.** (2010). Neuropsychology of P300. In S.J. Luck & E.S. Kappenman (Eds.), *Handbook of event-related potential components* (pp. 159-187). New York, New York: Oxford University Press. **Johnson, R. & Donchin, E.** (1978). On how P300 amplitude varies with the utility of eliciting stimuli. *Electroencephalography and Clinical Neurophysiology, 44*(4), 424-437.

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