ERP effects for quantifier complexity, priming, and truth-value in an auditory/visual verification task

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Objectives

We examined the processing of quantified sentences in an auditory/visual verification task to probe:

i. truth-value/quantifier-type influences on the N400 ERP response

ii. ERP markers of quantifier complexity.

Introduction

Concerning (i):

- N400 has been reported to be insensitive to truth-value/negation in verification paradigms [2,3];
- N400 modulated by subject/predicate relatedness (e.g., ROCK>BIRD in *A robin IS/IS-NOT a ROCK/BIRD*)
- **BUT**: when controlling for pragmatically unnatural uses of negation, N400 amplitude may be modulated by truth-value (False>True) [5].

Concerning (ii):

- Additional working memory resources are recruited in processing proportional quantifiers [4];
- **BUT** time-course of complexity effects has not been investigated using ERPs.

Methods

We presented quantified sentences auditorily while participants simultaneously viewed arrays of colored shapes (cf. Fig. 1). Shape/color combinations were constructed to yield 8 conditions varying quantifier/truth-value.

Stimuli were as follows:

- 14 colored shapes
- Even contrast ratio for ALL/NONE (7 yellow-circles/7 blue-squares)
- Opposing 2 : 5/5 : 2 ratios for MOST/SOME (e.g., 2 yellow-/5 blue-circles and 5 blue-/2 yellow-squares)
- False conditions used color/shape-predicates not present in the images (unprimed).

We tested adult native English speakers (N=10) who provided (mis)match judgments after each trial. We recorded continuous EEG (32 channels, Biosemi-Active-2) and examined ERP mean amplitudes for successive 100 ms windows over 1200 ms epochs (-200-0 ms baseline). Signals were time-locked to (i) predicate onset to examine quantifier-type influences on truth-value and (ii) onset of the quantifier to test for complexity effects.

Results

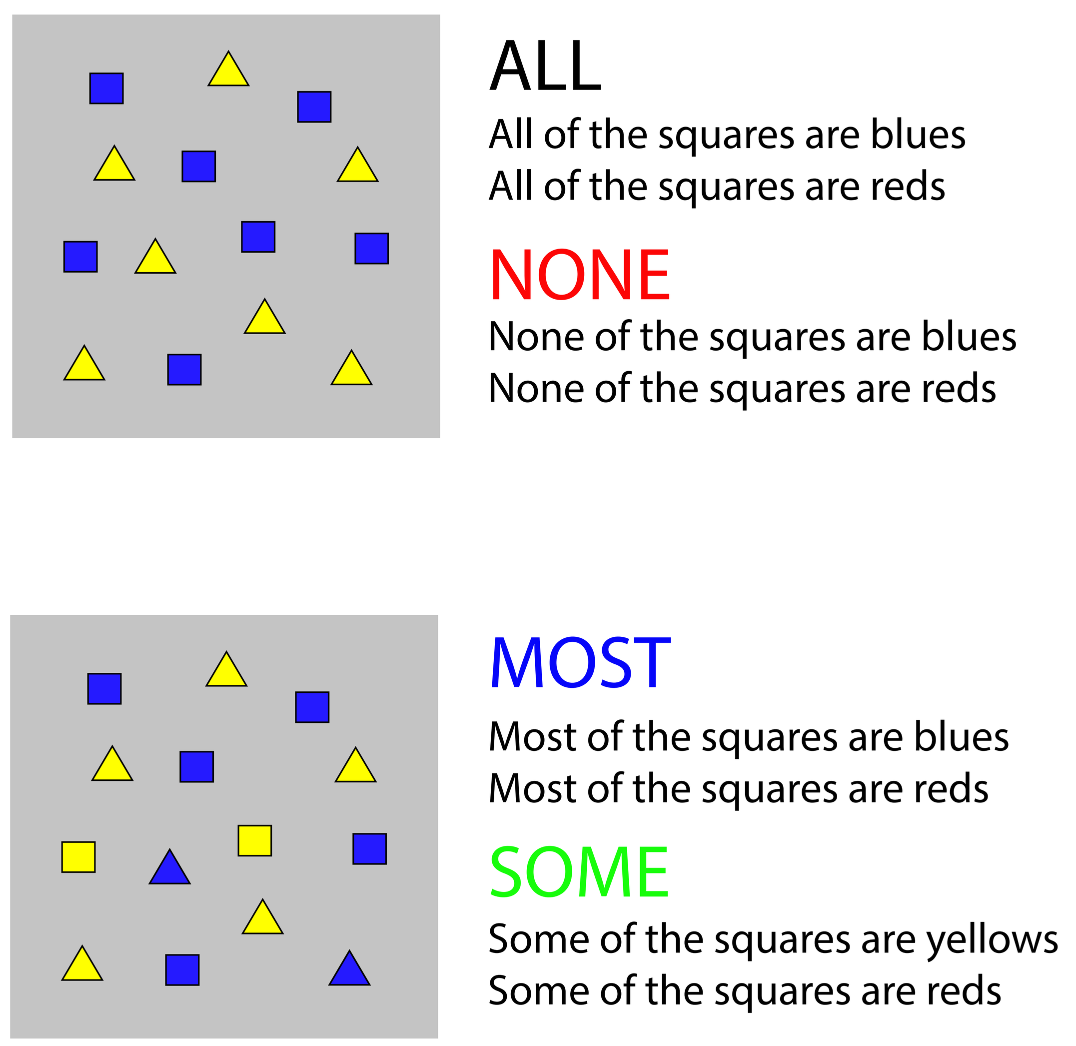

Figure 1: Stimuli Design

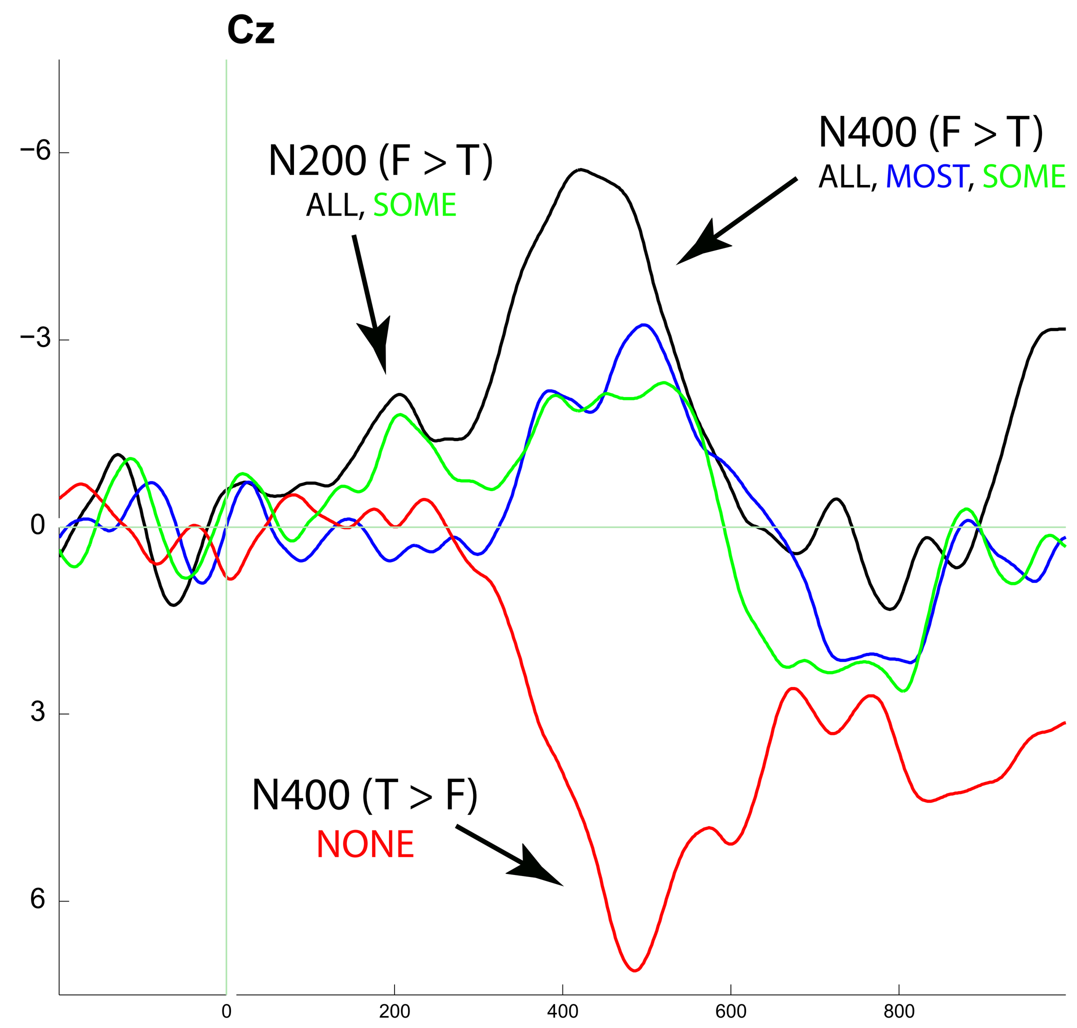

Figure 2: (False - True) difference waves at predicate onset

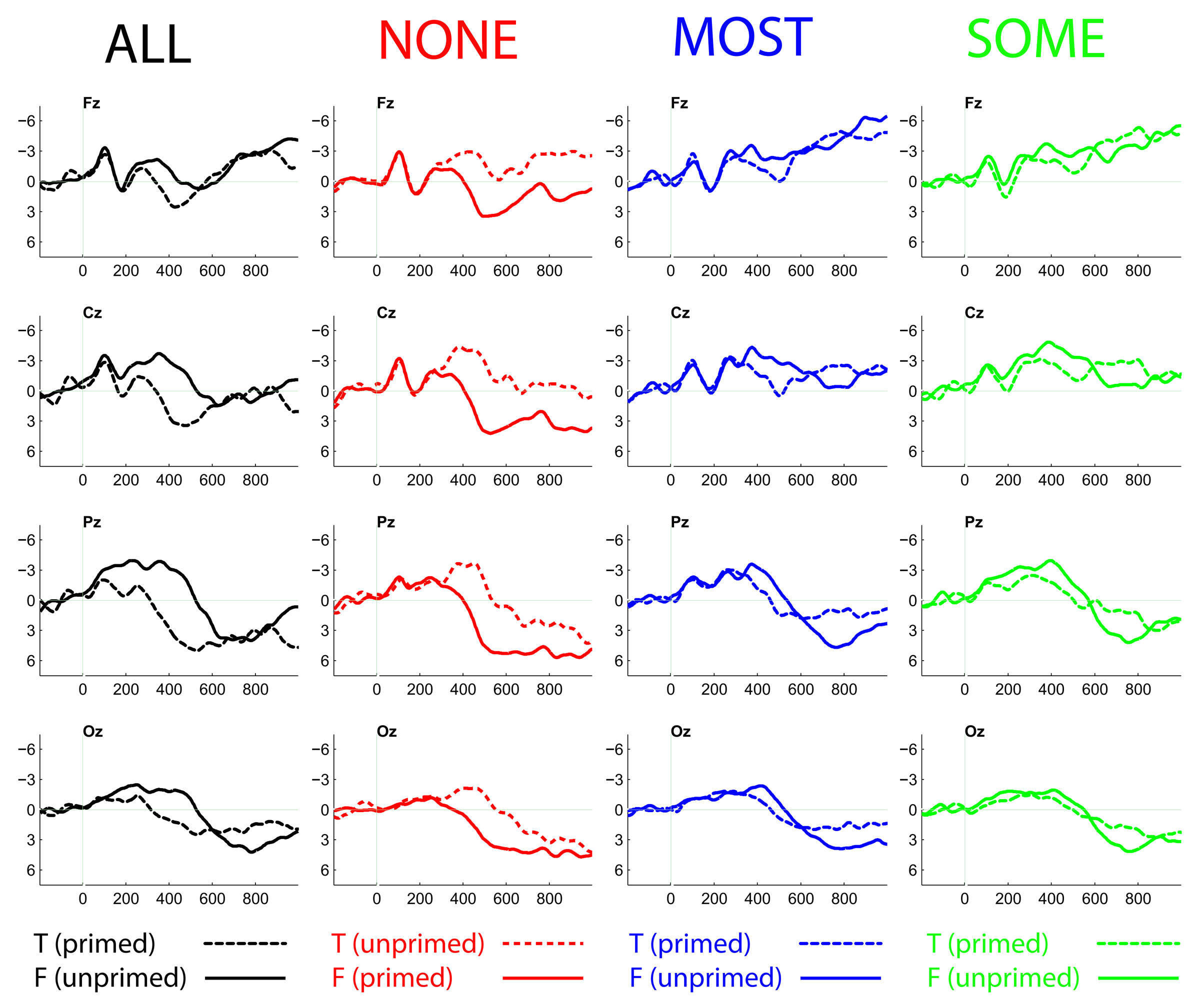

Figure 3: All conditions, time-locked to the predicate onset, midline electrode

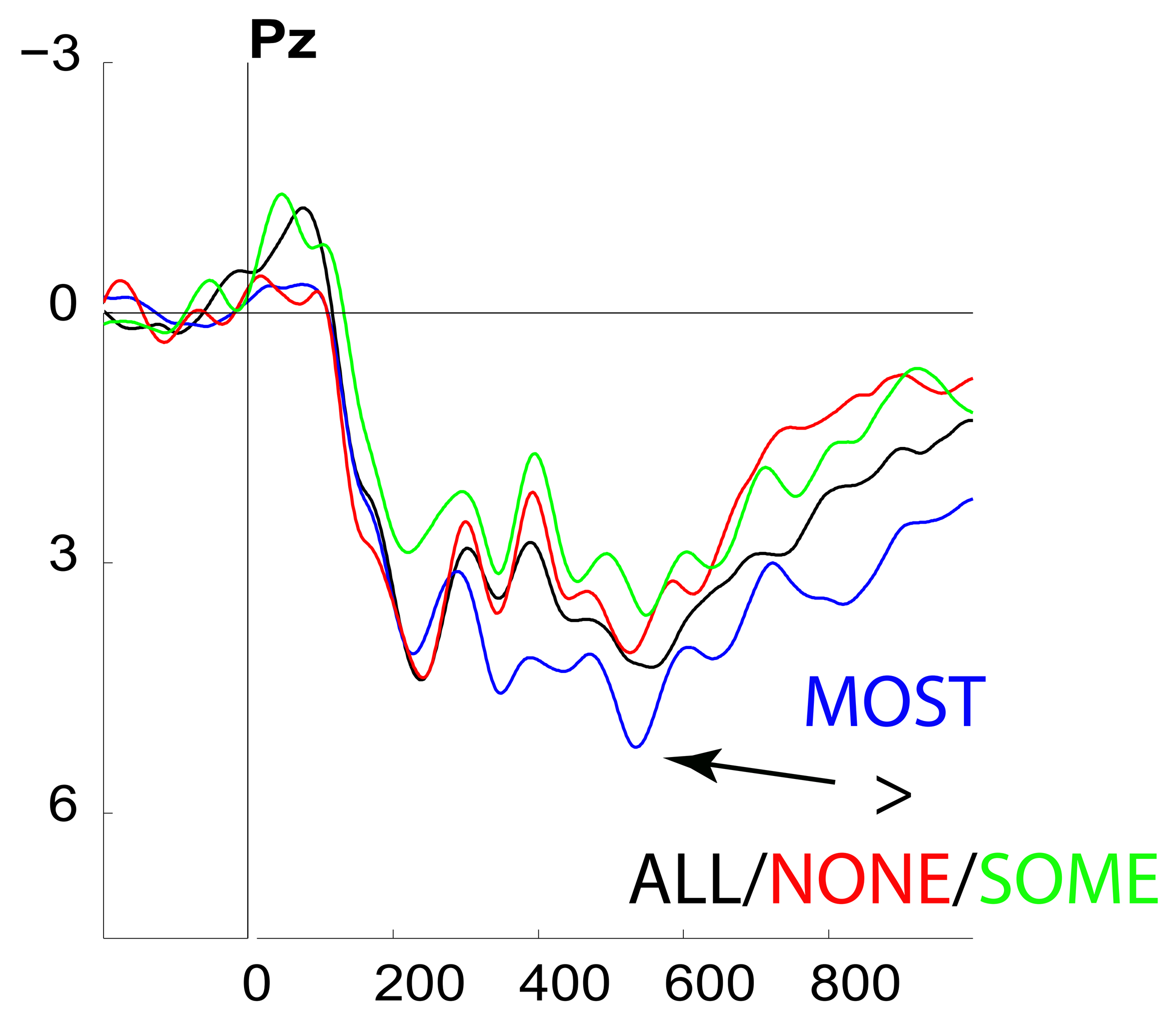

Figure 4: Complexity effects: ERPs at quantifier onset

Discussion

Priming and Truth-Value. Predicates show opposite polarity N400 effects for ALL (False>True) relative to NONE (True>False), along with subsequent P600s (False>True) for both ALL/NONE. SOME/MOST yield a N400/P600 profile (False>True):

- N400 is driven by priming the expected auditory continuation;
- Truth-value does not modulate N400 amplitude, in line with earlier findings [2]. **BUT** consistent False>True effects modulate the P600.

Priming & Prediction Effects on N200. Predicates show earlier negativity for ALL relative to NONE, and for SOME relative to MOST (False>True, peaking ~200ms). We relate this early negativity for ALL/SOME to Phonological Mismatch Negativities (PMMNs; [1]):

- ALL combined with priming for SQUARES restricts the space of expectations specifically to **blue**. False cases then give rise to PMMNs at the onset of an unexpected predicate;
- NONE only predicts **not blue**, so the hypotheses space at the onset of the predicate is too vague for early mismatches;
- SOME asks for sets of minimal cardinality (**blue triangles**, yellow squares). Priming for SQUARES thus leads to strong predictions for yellow and PMMNs in False conditions;
- MOST should restrict expectations to sets of maximal cardinality. But it is known that maintenance of both sets is independently required for verification [4]. Thus no specific expectation to cue early mismatches.

A Marker of Quantifier Complexity? Time-locking to the onset of the quantifiers (cf. Fig. 4) reveals a positivity for MOST > ALL/NONE/SOME, beginning at ~350-450 ms:

- This early positivity is consistent with complexity effects associated with initial encoding of higher-order quantifiers, and reflecting the need for continued maintenance of the cardinalities for the contrasting sets.

References

[1] Connolly, J. F., Phillips, N. A. (1994). Event-related potential components reflect phonological and semantic processing of the terminal word of spoken sentences. *J. of Cognitive Neuroscience.* **[2]** Fischler I., Bloom P., Childers D., Roucos S., Perry N. (1983) Brain potentials related to stages of sentence verification. *Psychophysiology.* **[3]** Kounios J, Holcomb P. (1992) Structure and process in semantic memory - evidence from event-related brain potentials and reaction-times. *J. of Experimental Psychology: General.* **[4]** McMillan, C. T., R. Clark, P. Moore, C. Devita, and M. Grossman (2005). Neural basis for generalized quantifier comprehension. *Neuropsychologia.* **[5]** Nieuwland MS, Kuperberg GR. (2008) When the truth isn't too hard to handle: An event-related potential study on the pragmatics of negation. *Psychological science.*