



Research report

Incremental comprehension of spoken quantifier sentences: Evidence from brain potentials

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ABSTRACT

Do people incrementally incorporate the meaning of quantifier expressions to understand an unfolding sentence? Most previous studies concluded that quantifiers do not immediately influence how a sentence is understood based on the observation that online N400-effects differed from offline plausibility judgments. Those studies, however, used serial visual presentation (SVP), which involves unnatural reading. In the current ERP-experiment, we presented spoken positive and negative quantifier sentences (“Practically all/practically no postmen prefer delivering mail, when the weather is good/bad during the day”). Different from results obtained in a previously reported SVP-study (Nieuwland, 2016) sentence truth-value N400 effects occurred in positive and negative quantifier sentences alike, reflecting fully incremental quantifier comprehension. This suggests that the prosodic information available during spoken language comprehension supports the generation of online predictions for upcoming words and that, at least for quantifier sentences, comprehension of spoken language may proceed more incrementally than comprehension during SVP reading.

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1. Introduction

Quantifier expressions like ‘most’ or ‘few’ are crucial for people to communicate information about the world in an efficient manner. People use quantifiers to express to what extent a certain property holds true for the entities belonging to a larger set (e.g. “Most whiskies in Edinburgh pubs are Scotch”). In philosophical and linguistic theories of meaning, quantifiers therefore are commonly associated with their impact on sentence truth-conditions (e.g. Partee, 1991), the conditions that make a sentence ultimately true or false. Whereas truth-conditions are typically considered without regard to how the sentence unfolds in time when people listen to or read a sentence, quantifier meaning may influence the listener’s comprehension of the unfolding sentence before it is finished. A question thus arises: Do people incrementally incorporate the meaning of quantifier expressions to understand an unfolding sentence? Previous research has sought an answer to this question by examining whether and when on-line measures of comprehension (e.g., eye-movements or ERPs) correspond to the meaning that readers ultimately extract from quantifier sentences as reflected in offline measures (e.g., plausibility or truth-

value judgments). This research typically examines whether truth-value or plausibility impacts online comprehension in positive and negative quantifier sentences alike. Most studies to date report that on-line and offline measures show different patterns of quantifier comprehension, suggesting that quantifier meaning does not fully incrementally impact the interpretation of an unfolding sentence (e.g., Kounios and Holcomb, 1992; Urbach and Kutas, 2010). However, previous studies examined comprehension of written language, using artificial reading procedures such as serial visual presentation. It is an open question whether people incorporate quantifier meaning in an incremental manner when listening to spoken sentences. The present study investigated this issue by recording neurophysiological responses to spoken quantifier sentences.

1.1. Quantifiers and incremental interpretation

Previous ERP research on quantifier comprehension has investigated the processing consequences of sentences that do not correspond to what people hold to be true or plausible in the real world (Kounios and Holcomb, 1992; Nieuwland, 2016; Urbach et al., 2015; Urbach and Kutas, 2010). The dependent measure in these studies is the N400 ERP component (Kutas and Hillyard, 1980), a negative ERP deflection peaking around 400 ms after word-onset. N400 amplitude is smaller when the retrieval of word-associated information in semantic memory is facilitated by

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the context (e.g., Kutas and Federmeier, 2011), potentially via pre-activation of relevant information (e.g., Ito et al., 2016). Words that render a sentence true elicit a smaller N400 than words that render a sentence false (Nieuwland and Kuperberg, 2008; Nieuwland and Martin, 2012), reflecting the facilitated comprehension of words that render a sentence true. In research on quantifier comprehension, the question of interest is whether such sentence truth-value N400 effects occur in positive and negative quantifier sentences alike.

In the first ERP study on quantifier comprehension, Kounios and Holcomb (1992) found no effect of quantifier type (positive or negative) on the N400 to the last words of sentences like “All/No rubies are gems/spruces”, even though the sentences were evaluated correctly after they were finished. Kounios and Holcomb concluded that quantifier interpretation is delayed and that initial semantic processes as indexed by the N400 are insensitive to the compositional meaning of the sentence, and only reflect lower-level lexical-associative relationships (cf. Fischler et al., 1983). However, the results are also consistent with a step-wise account of sentence verification, in which readers initially compute and evaluate an affirmative proposition before applying negative quantifier meaning (Carpenter and Just, 1975).

A different pattern was observed by Urbach and Kutas (2010). In positive and negative quantifier sentences (e.g., “Almost all/Almost no groupies follow singers/boys”), atypical objects like ‘boys’ elicited the same N400 regardless of quantifier type, whereas typical objects like ‘singers’ elicited smaller N400s following positive quantifiers compared to negative quantifiers. The authors took these results as evidence for partial incremental comprehension of negative quantifiers, as the online N400 measures did not mirror the post-sentence plausibility ratings (atypical objects were judged less plausible than typical objects in positive sentences, but more plausible in negative sentences).

In a very recent study by Urbach et al. (2015), this pattern of results changed to a more incremental pattern (i.e., smaller N400 for implausible sentences regardless of quantifier type) when a supportive discourse preceded the quantifier sentences (e.g., “Alex was an unusual toddler. Few/Most children prefer vegetables/sweets”). However, this incremental pattern occurred *only* when participants were not required to explicitly evaluate plausibility of the sentences. A partial incremental pattern similar to that of Urbach and Kutas (2010) was observed when participants made plausibility judgments following each sentence. The authors concluded that task variables appear to impact the speed and/or depth of quantifier interpretation, although their discussion fell short of an explanation for why quantifier interpretation would be slower or less deep when people are engaged in a task that explicitly probes quantifier sentence meaning.

To account for the different patterns observed in previous studies, Nieuwland (2016) recently proposed a prediction-based account of online quantifier interpretation: the precise pattern in which quantifiers are understood depends on the extent to which quantifier meaning is incorporated into a prediction for upcoming words. This proposal was based on an ERP study wherein participants read sentences such as “Practically all/no postmen prefer delivering mail when the weather is good/bad”. When positive and negative quantifiers had similarly low cloze-values, a pattern comparable to that reported by Kounios and Holcomb (1992) was observed, whereas when positive and negative quantifiers had similarly high cloze-values, sentence truth-value N400-effects occurred regardless of quantifier type (i.e., a fully incremental pattern; see also Nieuwland and Martin (2012)). Quantifier sentences are thus understood neither always in two sequential stages, nor always in a partial-incremental fashion, nor always in a maximally incremental fashion. Fully incremental quantifier interpretation only occurs when quantifiers are incorporated into

sufficiently strong online predictions for upcoming words.

The prediction-based account proposed by Nieuwland (2016) captures the range of previous results on online quantifier comprehension, which all involved reading. In reading ERP studies, words are typically presented one at a time in the middle of the screen (serial visual presentation, SVP), at a fixed pace. While SVP has the benefit of minimizing eye-movement artefacts during EEG recording, this procedure is unnatural because it does not allow participants to read at their own pace and to preview upcoming information. Importantly, the ability to generate online predictions may be limited by SVP. One relevant factor is the word presentation duration. Uncomfortably fast-paced SVP may make it difficult for people to generate predictions even when they read relatively high-cloze sentences (e.g., Dambacher et al., 2012), whereas slow-paced SVP may allow people more time to generate predictions even in low-cloze sentences. Interestingly, Kounios and Holcomb (1992), who found no effect of quantifier type on the N400, had a more rapid presentation rate per word on average (850 for 3 words such as “No dogs are”). A second important factor is that spoken sentences contain rich prosodic information that aids comprehension (Cutler et al., 1997; Frazier et al., 2006), which may facilitate the online generation of predictions. In the present study, we therefore examine the comprehension of spoken quantifier sentences.

1.2. Incrementality in spoken language comprehension

Spoken language comprehension typically proceeds in a highly incremental manner: at each moment in time, listeners effectively use the smallest cues that are available (phonemes) to interpret the unfolding sentence and sometimes to generate predictions about what comes next (Altmann and Mirković, 2009). The interpretation of a spoken word therefore starts as early as its first phoneme, where lexical candidates that match the input may become activated in parallel until further information narrows down the set of candidates to one uniquely identifiable word (e.g. Marslen-Wilson, 1987). Moreover, ERP studies have shown that when listeners generate a prediction about which word comes next, the first bit of input that is inconsistent with the predicted input elicits processing costs as reflected in the N400 (Van Petten et al., 1999).

These online predictions about upcoming words are based on the meaning of the unfolding sentences, but they are also strengthened by co-articulation, i.e., the assimilation of the pronunciation of two neighbouring words (Öhman, 1966). The pronunciation of one word thus typically provides prosodic information about the next word. Listeners can benefit from co-articulation in similar ways as readers benefit from parafoveal preview of upcoming words during natural reading: both phenomena will facilitate recognition and comprehension of upcoming words (Rayner, 1998). Co-articulation might therefore contribute to the relatively earlier N400 onset in spoken language compared to SVP (Kutas et al., 1987; Van Berkum et al., 2003; but, see also Hagoort and Brown (2000a)). This earlier onset is only observed in spoken sentences, because when the words of a spoken sentence are presented at a fixed rate, the N400 time-course is more comparable to SVP reading (Holcomb and Neville, 1991). In addition to co-articulation, comprehension is also facilitated by sentence prosody, as listeners are able to use prosody to predict utterance length and determine phrase boundaries (e.g. Cutler et al., 1997).

The comprehension of spoken words is thus strongly influenced both by the prosodic and linguistic context in which they appear. Compared to SVP, where a word presented as a whole confirms or disconfirms a prediction, listeners can determine whether or not the word matches the prediction based on only a tiny bit of spoken input. Also compared to SVP reading, listeners benefit from co-articulation, as more information is available to generate a prediction of the next word. Because predictive

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