Less than a Sentence is not Enough – An Eyetracking Study on Scope Interpretation

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Background of the present study: Online studies of quantifier and negation processing suggest that not all aspects of scope taking expressions are interpreted immediately. A number of previous studies concluded that downward entailing (DE) quantifiers such as *less than half* lead to severe processing delays as compared to upward entailing (UE) ones, such as *more than half* (e.g. [1]), as does the interpretation of negation (e.g. [2]). Perhaps unsurprisingly, then, the non-incremental interpretation of scope bearing elements seems to extend to multiply quantified sentences, as suggested by an eyetracking during reading study on the relative scope of quantifiers by [3] with scope interpretation delayed until the end of the sentence. The study of multi-operator sentences is nevertheless crucial because such constructions unambiguously rely on truly compositional processes, whereas for simpler sentences a shallow processing account based on simple lexical associations may be a viable theoretical alternative. The purported violation of incrementality has not gone unchallenged, though. In particular, it has been shown that pragmatic factors such as world knowledge and discourse context bear important influences on the time course of scope interpretation (e.g. [4,5,6]). For negation, [7] have proposed a pragmatic account based on *questions under discussion* (QUDs, [8]) essentially claiming that the delay is caused by the need to accommodate certain discourse conditions imposed by negation. Our eyetracking during reading study investigates the time course of semantic interpretation of sentences containing a quantifier and negation (see ex. (1)-(6)) with and without context.

Experimental results: Exp. 1 ($N = 48$) established a clear complexity metric with overadditive composition effects of operators but did not yet address incrementality. Participants read sentences containing UE vs. DE quantifiers in initial position and negated vs. positive predicates (e.g. *not blue* vs. *blue*; see ex. (1); verification task in all experiments) in the sentence-final region of interest (ROI). Relative scope was fixed because negation appeared in a scope island. The final ROI contained the negation, provided the second semantic argument of the quantifier and completed the sentence. As predicted based on theoretical considerations, effects of semantic complexity showed up no earlier than that ROI: Regression path durations (RPDs) were longer for DE than UE quantifiers, but only in negated conditions (Fig. 1 a; all reported effects were significant in mixed effects models). Exp. 2 ($N = 40$) used these complexity differences as a time index for compositional scope computation in quantifier-negation sentences out of discourse context. To test for incremental complexity effects, the position of the main verb was also manipulated (cf. ex. (2) vs. (3); strong surface-scope preference established in a pretest). We expected delayed semantic interpretation in (3) because the main verb was presented several words after the negation. In (2), we considered incremental effects likely, since the negation was presented simultaneously with the main verb and, as in Exp. 1, completed a minimal sentence. Contrary to our expectations, complexity effects were delayed to the final ROI, irrespective of verb position (Fig. 1 c). Exp 3. ($N = 48$) embedded clefted versions of the same sentences (ex. (6); relative scope again fixed by scope island) in discourse contexts that introduced positive and negative properties (e.g. *to play* or *not to play*) as well as a the QUD "how many" individuals have those properties. Based on the existing literature, we expected incremental effects in contextually licensed sentences. Contextual embedding led to earlier and sustained effects of negation (Fig. 1 b), but properties of the quantifier still only affected the clause-final ROI.

Discussion: The different time course observed for Exps. 2 and 3 resulting from the contextual establishment of the QUD shows that discourse pragmatics is an important prerequisite for the realtime interpretation of scope. However, finding an effect of monotonicity still only at the end of the clause indicates that scope interpretation proceeds in an essentially non-incremental way. This is an interesting finding because the verbal information was given information already specified in the discourse context. The processing of scopal operators thus depends on a larger domain than just the operators themselves, seemingly a complete minimal sentence.

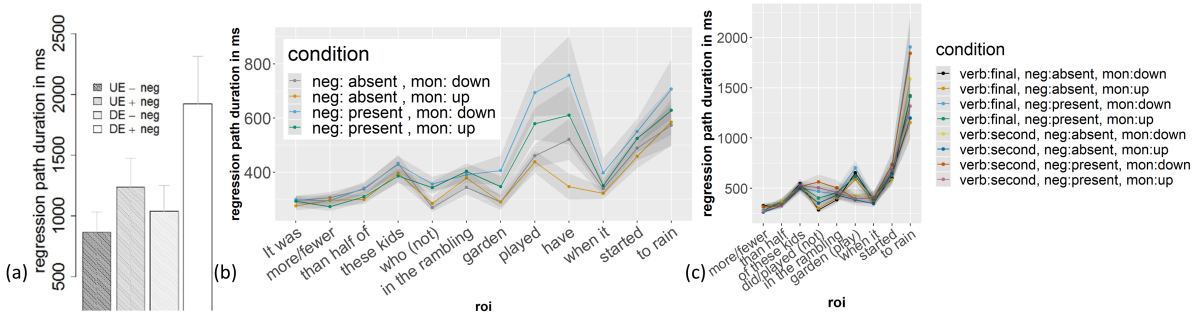

Figure 1: Regression path durations (+95% confidence intervals), i.e. the time of all fixations summed up from first entering a ROI until it is left to the right (a: sentence final ROI in Exp. 1; b: all ROIs in Exp. 3; c: all ROIs in Exp. 2).

Example Item Experiment 1 (subsequent picture verification task ignored here):

(1) Auf/On | {mehr/weniger} als die Hälfte der Quadrate |trifft zu, |dass sie |(nicht) blau sind.
{more/fewer} than the half of squares |applies |that they |(not) blue are

'It holds for {more/fewer} than half of the squares that they are (not) blue.'

Example Item Experiment 2 (subsequent picture verification task ignored here):

(2) {Mehr/Weniger/More/Fewer} als |die Hälfte |dieser Kinder |spielten (nicht) |im weitläufigen |Garten,...
than |half |of these kids |played (not) |in the rambling |garden...

(3) {Mehr/Weniger/More/Fewer} als die Hälfte |dieser Kinder |haben (nicht) |im weitläufigen |Garten gespielt,...
than half |of these kids |have (not) |in the rambling |garden played...

(4) ...|als es |anfing |zu regnen.
...|when it |started |to rain

Example Item Experiment 3 (subsequent picture verification task ignored here):

(5) [Preceding Context:]
Ida's parents invited the kids from the neighborhood to her birthday party. After lunch they all played in the garden. When it started to rain, Ida's parents decided to open up the living room for the kids. Some of the kids didn't want to play in the garden anymore whereas others stayed outside and played in the rain.

(6) Es waren/It was | {mehr/weniger/more/fewer} |als die Hälfte |dieser Kinder, |die (nicht) |im weitläufigen |Garten |gespielt |haben,
|than half |of these kids |who (not) |in the rambling |garden |played |have
|als es |anfing |zu regnen.
|when it |started |to rain

References: [1] Urbach & Kutas (2010), *JML* 2 (63). • [2] Kaup et al. (2007), in Schmalhofer & Perfetti (eds.): *How is negated information represented?* • [3] Bott & Schlotterbeck (2015), JoS 32. • [4] Nieuwland (2016), *J. Exp. Psychol. Learn.Mem. Cogn.* • [5] Freunberger & Nieuwland (2016), *Brain Research* 1646. • [6] Nieuwland & Kuperberg (2008), *Psychol. Sci.* 19. • [7] Tian & Breheny (2010), *Psychol. Sci.* 19. • [8] Roberts (1996/2012), *Sem. & Prag.* 5.