The approximate number sense bootstraps scalar implicature of comparatively modified numerals in impoverished contexts

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Recent years have seen an increased interest in stochastic expectations in the semantics and pragmatics of language (cf. Lassiter, 2009; Franke et al., 2016). Our talk is on the scalar implicatures of numerals modified by the comparative quantifiers '*more than*' and '*fewer than*.' Comparatively modified numerals express numerical vagueness, uncertainty, and ignorance—and pose an interesting puzzle: How do interlocutors limit their expectations about potential values in the face of uncertainty?

The sentence '*London has more than 1000 inhabitants*' (taken from Cummins, Sauerland, & Solt, 2012) exemplifies two sources for constraining expectations: world knowledge and the numeral itself. When the sentence is uttered out of the blue it sounds odd because world knowledge tells us that London has a lot more inhabitants than 1000 and so the range we expect—even if we are uncertain about the exact population (prior-based uncertainty)—must be much higher than suggested by '*more than 1000,*' which, however, is also vague about the range of potential values (language-based uncertainy).

Semanticists have seen prior-based uncertainty constrained by context as something that overshadows expectations raised by the modified numeral itself, and have consequently focused their attention on impoverished contexts such as '*the number of signatures on a petition*' (taken from Cummins et al., 2012). Without sufficient information about the cause of the petition, the method of collection, and the community in which signatures are collected, speakers may be very limited in their ability to constrain their (prior) expectations. As a result, it is widely assumed in the literature that modified numerals do not generate scalar implicature in impoverished contexts as the comparative quantifier signals that the speaker is ignorant of the exact number (Krifka, 1999; Fox & Hackl, 2006; Nouwen, 2015).

Cummins et al. (2012) were able to show experimentally that comparatively modified numerals do generate scalar imlicature in impoverished contexts, and that it is not world knowledge but the numerical property of roundness which constrains expectations about potential values in this type of context. In their experiments, a priming context, such as '*We need more signatures on the petition. How many did we get?*' is followed by an answer containing an estimate using a comparatively modified numeral. Participants were asked to indicate the lower and upper bounds of the range of expected values and the most likely potential value. They found the rounder the numeral is, the bigger the expected range, and the further the most likely value is away from the numeral.

Contrary to Cummins et al. (2012) we argue that it is the approximate number sense (Dehaene, 2011) which bootstraps scalar implicature of comparatively modified numerals in impoverished contexts. We use the same experimental paradigm as Cummins et al. (2012), but with more numerals per roundness level and across different orders of magnitude. Firstly, we show that numerals' magnitude has a much stronger effect on range size and distance of the most likely value than their roundness. Secondly, we show the existence of two Weber fractions (Fechner, 1860) in relation to magnitude: The distance of the most likely value remains constant across different orders of magnitude. When estimating range limits, participants have a strong preference for certain round numbers (Dehaene & Mehler, 1992; Jansen & Pollmann, 2001). Participants shift their boundary preference when the distance between the boundary and the numeral would be smaller than a second Weber fraction. Thirdly, the two Weber fractions are numerically similar to the acuity of the approximate number sense, which could also be the source of language-based uncertainty.

Cummins, C., Sauerland, U., & Solt, S. (2012). Granularity and scalar implicature in numerical expressions. *Linguistics and Philosophy, 35*(2), 135-169. DOI: 10.1007/s10988-012-9114-0.

Dehaene, S. & Mehler, J. (1992). Cross-linguistic regularities in the frequency of number words. *Cognition*, 43(1), 1-29. DOI: 10.1016/0010-0277(92)90030-L.

Dehaene, S. (2011). *The Number Sense: How the Mind Creates Mathematics, Revised and Updated Edition*. Oxford University Press, USA.

Fechner, G. T. (1860). *Elemente der Psychophysik [Elements of psychophysics]*, volume 2. Leipzig: Breitkopf und Härtel.

Fox, D. & Hackl, M. (2006). The universal density of measurement. *Linguistics and Philosophy, 29*(5), 537-586. DOI: 10.1007/s10988-006-9004-4.

Franke, M., Dablander, F., Schöller, A., Bennett, E., Degen, J., Tessler, M. H., Kao, J., & Goodman, N. D. (2016). What does the crowd believe? A hierarchical approach to estimating subjective beliefs from empirical data. In Papafragou, A. (Ed.), *Proceedings of CogSci 38*, (pp. 2669-2674). Cognitive Science Society.

Jansen, C. J. M. & Pollmann, M. M. W. (2001). On Round Numbers: Pragmatic Aspects of Numerical Expressions. *Journal of Quantitative Linguistics*, 8(3), 187-201. DOI: 10.1076/jqul.8.3.187.4095.

Krifka, M. (1999). At Least Some Determiners Aren't Determiners. In K. Turner (Ed.), *The semantics/pragmatics interface from different points of view. Current research in the semantics/pragmatics interface*, volume 1 (pp. 257-292).

Lassiter, D. (2009). Vagueness as Probabilistic Linguistic Knowledge. In Vague- ness in Communication, Lecture Notes in Computer Science, (pp. 127-150). Springer, Berlin, Heidelberg. DOI: 10.1007/978-3-642-18446-8-8.

Nouwen, R. (2015). Modified numerals: The epistemic effect. In Alonso-Ovalle, L. & Menéndez-Benito, P. (Eds.), Epistemic Indefinites: Exploring Modality Beyond the Verbal Domain. Oxford Scholarship Online. DOI: 10.1093/acprof:oso/9780199665297.003.0011.