



April 23, 14

Dear Editorial Board,

Please find enclosed a manuscript titled “Nonliteral Understanding of Number Words” for consideration in *PNAS*. My co-authors for this work are Jean Wu, Leon Bergen, and Noah Goodman.

Human communication is full of nonliteral language, ranging from metaphor to irony and hyperbole. For successful communication to take place, listeners need to go beyond the literal meaning of an utterance to infer the speaker’s intended meaning. In addition, speakers do not always use language to describe the objective state of the world, but also to communicate their subjective opinions and emotions. These aspects of language—nonliteral use and affective subtext—are critical to understanding the nature of linguistic meaning and communication. While these areas have been studied across many fields, the approaches in psychology and linguistics have been largely qualitative, with little focus on predicting the quantitative details of people’s figurative interpretation. In more quantitative disciplines such as computer science, the focus has been on identifying surface features of figurative and affective language and less on explaining the computational basis of nonliteral language understanding. We believe that the latter serves an important scientific purpose and aim to address this gap.

We present a computational model of nonliteral understanding that builds upon core theories of communication and recent formal models of pragmatics. We solve a crucial problem in these recent formal models (including our own): they are unable to predict interpretations of an utterance that are false under its literal meaning. We focus on the nonliteral interpretation of number words, in particular hyperbole. Hyperbole is a common figure of speech that uses exaggeration to convey emphasis and emotion. We theorized that listeners incorporate prior knowledge and reasoning about the speaker’s communicative goal to infer the meaning of a potentially hyperbolic utterance. We show that our computational model produces nonliteral and affective interpretations for a set of numeric utterances.

In order to verify our model predictions, we conducted two experiments to elicit people’s intuitive interpretations of numeric utterances. In Experiment 1, participants read dialogues that contain numerical utterances about the price of an item (e.g. “Bob said: ‘The watch cost  $x$  dollars.’”) and give ratings about the item’s actual price. We systematically manipulated  $x$  and the item type to measure participants’ interpretations given different background knowledge of the probability of the statement being literally true. In Experiment 2, participants read dialogues containing numerical utterances that are either literally true or hyperbolic (e.g. “Bob bought a watch that cost  $y$  dollars. Bob said: ‘The watch cost  $x$  dollars.’”). They then rate the probability that the speaker thinks the item is expensive. Our model’s predictions closely matched human data. These results show that our model successfully captures a range of effects in the interpretation of

number words, both nonliteral and affective.

In summary, our computational model integrates background knowledge, principles of communication, and communicative goals to quantitatively predict humans' interpretation of nonliteral language. This framework sheds light on the nature of communication, marking a significant advancement in the flexibility and richness of formal models of language understanding. Not only is nonliteral language an important puzzle piece in psychology and linguistics, it is also an area of great interest in artificial intelligence and natural language processing. If we hope to create machines that can respond appropriately to human language in its full complexity, we need a computational model that considers speaker intent and rich dimensions of linguistic meaning to arrive at the correct interpretation. Our model represents the first step towards this goal. For these reasons, we believe our findings will be of broad interest across the fields of psychology, cognitive science, linguistics, and computer science, as well as to the general public, and is ideally suited to the *PNAS* readership.

We hope you find this work to merit further scrutiny by additional experts. If you do, there are many scientists whose experience and expertise are suited to evaluating this manuscript, including: Mike Tanenhaus, Nick Chater, Terry Regier, Jeff Elman, Steven Pinker, and Amy Perfors.

If you have any questions or require any clarifications about this work, please do not hesitate to contact us.

Sincerely,

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