THE EMERGENCE OF FOCUS IN AN EXPERIMENTAL COMMUNICATION GAME

GARETH ROBERTS*[1] and JON STEVENS[2]

*Corresponding Author: gareth.roberts@ling.upenn.edu
[1]Department of Linguistics, University of Pennsylvania, Philadelphia, PA, USA
[2]Department of Linguistics, The Ohio State University, Columbus, OH, USA

We report an experiment investigating the emergence of focus, the prosodic or morphosyntactic marking of *critical elements* (Schmitz, 2008) in a sentence.

Stevens (2016) argued for a theory of focus based in information theory (Shannon & Weaver, 1949; Schmitz, 2008; Bergen & Goodman, 2015). Language users must deal with *noise* – the random deletion or alteration of parts of a signal. A solution is to compensate by adding redundancy (e.g., greater prosodic or morphosyntactic emphasis). However, redundancy costs both effort and time, so we should expect speakers to restrict redundancy to critical elements, particularly when effort and time pressures are high. (Redundancy on critical elements will be referred to here as *critical redundancy*, as compared with *non-critical* redundancy on other elements.) These factors should be expected to operate over multiple timescales. In a single interaction, speakers respond dynamically to perceived noise, time and effort pressures (Krauss & Weinheimer, 1964; Clark, 1996; Brennan & Clark, 1996). Developmentally, language learners acquire strategies for adding redundancy (Romaine, 1984). Over generations, such strategies can be expected to become grammaticalized as focus systems (Tamariz & Kirby, 2016).

We thus expect focus-like behavior to emerge and evolve in any communication system that involves sending messages under similar constraints and make the following predictions: (1) Overall message length should vary according to time and effort costs; (2) longer messages should differ from shorter messages not only with respect to length – shorter messages should also have lower proportions of non-critical redundancy; (3) critical redundancy should be higher when noise is higher, both in an absolute sense and in a relative sense (more critical than non-critical redundancy); (4) unless noise and time pressures actually prevent accurate communication, communicative accuracy should remain relatively constant, because focus is designed to help maintain accuracy under different conditions.

We tested these predictions experimentally by having participants play a simple communication game. Players sat separately and took turns to be "Sender" or "Receiver". The Sender would see three grids, two with line figures (Figure 1; in

This paper is distributed under a Creative Commons CC-BY-ND license.
DOI:10.12775/3991-1.101

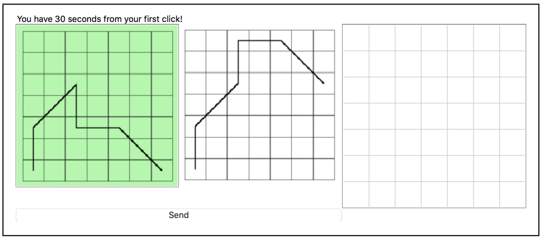

Figure 1. Sender's screen.

half the trials, the line figures overlapped by five cells), one selected in green. The third grid was blank. The Sender's task was to communicate the selected grid to the Receiver by clicking on as many (or as few) cells as they liked in the blank grid. The Receiver was then shown the same three grids and had to choose the correct line figure. Both participants were told if the Receiver chose correctly.

There were six conditions based on manipulating effort, noise, and time constraints (Table 1). For a cell to be sent, a Sender had to click it 15 times in the *High effort condition* and five in the *Low effort conditions*. In the Noise conditions, any clicked cell would be sent with a probability of $1 - (1 - d)^n$, where n equals the number of clicks made on the cell. Two values were used for d: 0.1 in the *High noise condition* and 0.4 in the *Low noise conditions*. (There were no 5s High effort or High noise conditions, as the time limit would restrict the number of clicks too much.)

Table 1. Experimental conditions

Time limit	Effort	Noise
30 seconds	High effort	High noise
30 seconds	Low effort	Low noise
5 seconds	Low effort (5s)	Low noise (5s)

Results and discussion. All predictions were supported. Message length (i.e., the number of cells sent) was greater than necessary in all conditions and varied according to noise and effort levels, remaining constant in the Low effort and Low noise conditions, and declining over time in the High effort and noise conditions. Per-cell click rate gave a measure of emphasis added to different line segments. The proportion of clicks devoted to non-critical (as opposed to critical) redundancy correlated positively with overall click rate ($r = 0.29, p < 0.001$), but the correlation was stronger ($r = 0.56$) in the High effort and High noise conditions, where there was greater pressure on participants. The distribution of effort took noise into account, with critical redundancy higher when noise was higher ($\beta = 58.57, SE = 7.56, t = 7.75, p < 0.001$). Overall mean accuracy was 97%, and did not differ significantly between conditions, with one exception: It was lower in the Low noise (5s) condition ($\beta = -0.07, SE = 0.02, t = -2.81, p < 0.01$), likely due to participants' underestimating noise.

Our results lend support to the information-theoretic account and suggest how focus systems in language might arise. This experiment focused on strategies emerging in one generation; it is likely that these become grammaticalized through transmission between generations. In further experimental work, we plan to investigate this using an iterated learning approach (Kirby, Griffiths, & Smith, 2014).

References

Bergen, L., & Goodman, N. D. (2015). The strategic use of noise in pragmatic reasoning. *Topics in Cognitive Science*, *7*(2), 336–350.

Brennan, S. E., & Clark, H. H. (1996). Conceptual pacts and lexical choice in conversation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *22*, 1482–1493.

Clark, H. H. (1996). *Using language.* Cambridge: Cambridge University Press.

Kirby, S., Griffiths, T., & Smith, K. (2014). Iterated learning and the evolution of language. *Current Opinion in Neurobiology*, *28*, 108–114.

Krauss, R. M., & Weinheimer, S. (1964). Changes in reference phrases as a function of frequency of usage in social interaction—a preliminary study. *Psychonomic Science*, *1*(5), 113–114.

Romaine, S. (1984). *The language of children and adolescents: The acquisition of communicative competence.* Oxford: Basil Blackwell.

Schmitz, H.-C. (2008). *Accentuation and interpretation.* New York: Palgrave MacMillan.

Shannon, C. E., & Weaver, W. (1949). *The mathematical theory of communication.* Champaign, IL: University of Illinois Press.

Stevens, J. (2016). Focus games. *Linguistics and Philosophy*, *39*(5), 395–441.

Tamariz, M., & Kirby, S. (2016). The cultural evolution of language. *Current Opinion in Psychology*, *8*, 37–43.