EMERGENCE OF SIGNAL STRUCTURE: EFFECTS OF DURATION CONSTRAINTS

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Recent work has investigated the emergence of structure in speech using experiments which use artificial continuous signals. Some experiments have had no limit on the duration which signals can have (e.g. Verhoef et al., 2014), and others have had time limitations (e.g. Verhoef et al., 2015). However, the effect of length constraints on the structure in signals has not been experimentally investigated.

Physical, functional or cultural pressures will effect how long signals in the real world can be. Obviously, speech is constrained by breath. Social and functional pressures for transmitting information quickly, succinctly and with little effort will also create pressures for signals to be shorter (Piantadosi et al., 2011).

Signal duration will affect signal structure. Having shorter signals may limit redundancy and influence how quickly signal units are discretised and reused.

We carried out a signal creation experiment. Participants created continuous auditory signals using a Leap Motion. The pitch of signals could be manipulated by the position of a participant's hand in relation to the Leap Motion (see Little et al., 2015, for a summary and justifciation of the paradigm). Participants created signals for a set of meanings. No two meanings had any features (shape, colour or texture) which were shared. Participants took part in two conditions. In the unconstrained condition, signals had no limit on duration (signals had an average length of 3 seconds, sd = 2.3). In the constrained condition, signals, monitored using a progress bar, could only be 1 second, shorter than 80% of signals in the unconstrained condition. The experiment had 3 phases, with the meaning space expanding in each phase; 5, 10, 15 meanings in phase 1, 2, 3 respectively. Each phase consisted of a practice session, a signal creation task (participants created signals for each randomly selected meaning), and a signal recognition task (participants heard their own signals and chose between 4 possible meanings for each).

In the constrained condition, participants were worse at recognising their signals (mean = 64% correct), than in the unconstrained condition (mean = 86%). Success levels were not significantly affected by the growth of the meaning space. This discrepancy in success suggests that in the constrained condition, participants may have had a harder time creating distinct signals. In the constrained condition, signals were much simpler, with a lot of participants relying on static pitch, rather than on patterns and pitch changes. We were able to measure the amount of movement within signals by calculating the variance of the signal trajectory coordinate values, and showed that the amount of movement in trajectories was significantly lower in the constrained condition than in the unconstrained condition (we compared a mixed linear model with a null model, $\chi^2(1) = 9$, $p < 0.001$).

We also found that in the unconstrained condition, there was a significant downward trend in the amount of systematicity in signals (measured by trajectory predictability given the rest of the signal repertoire) as the meaning space expanded. Signals for meanings introduced later were less predictable than those in earlier phases (we compared a mixed linear model with a null model, $\chi^2(1) = 4$, $p < 0.05$). This trend did not occur in the constrained condition, maybe suggesting that the limited signal duration stopped participants creating new strategies for new meanings, or constrained the use of redundant features in new signals, both of which would make signals less predictable.

Our results highlight why experimental studies need to consider the effects which time constraints will have on structure, systematicity and redundancy in artificial signals. Further, our time constraints impeded the production of distinct signals, generating a pressure for more efficient strategies for differentiating signals. One potential strategy, which accommodates the crowding of signal spaces, is the use of combinatorial structure. However, further experimental work needs to be done to see if this is the case.

Acknowledgements

Financial support from the ERC starting grant, ABACUS, project number 283435.

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