EXPLORING THE ROLE OF INTERACTION IN THE EMERGENCE OF LINGUISTIC STRUCTURE

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Iterated learning experiments show that pressures from communication and transmission can lead to the emergence of structure in language. However, languages are also supported by systems for turn taking (Levinson, 2016), sequence organization (Kendrick et al., 2014) and repair (Dingemanse & Enfield, 2015). It is therefore necessary to understand how these systems impact the emergence of structure in language. We discuss how experiments might investigate this and the wider role of interaction in language evolution.

1. The emergence of structure in iterated learning experiments

Language is shaped by being repeatedly learned, transmitted and used in interaction. While the roles of learning and transmission in cultural evolution have been explored effectively, we argue that aspects of interaction such as sequence organization and repair are equally important.

The iterated learning paradigm has been used to demonstrate that linguistic structure can emerge as a natural consequence of the mechanisms of cultural evolution (e.g. Kirby, Cornish & Smith, 2008). In experiments and models, individuals learn an artificial language, then transmit it to the next 'generation', who learn from this input and repeat this procedure. Over generations, the language changes according to selective pressures. A pressure for the language to be easy to learn causes the language to become simple and redundant. A pressure for effective communication, causes the language to become expressive. If both pressures apply, then compositional structures arise, allowing ease of learning but also expressivity (Kirby et al., 2015).

Results of iterated learning experiments suggest that the nature of language as a repeatedly learned and transmitted system is what provides the pressure for structure in language. Claidière et al. (2014) go further to demonstrate that providing an infrastructure for iterated learning can cause the emergence of structure in the behaviour of non human animals (baboons).

However, we argue that the iterated learning paradigm, as instantiated in existing experiments and models, provides a more complex framework than just a mechanism for transmitting information within and between generations. Experiments provide a pressure for use through communication games, and these games provide additional structures which are essential for conversation. These include constraints on turn taking and sequence organisation.

Each of these are processes which also contribute to the evolution of structure in the artificial languages (and may require an evolutionary explanation in themselves). As such, they may also explain the emergence of structure in real languages. In the next sections, we cover how communication games in iterated learning experiments work, how they provide structures for conversation, and how these could be manipulated to explore their impact on the evolution of language.

2. Communication games

Many experiments and models of iterated learning include a communication game between agents in the same generation as a way of providing a pressure for effective communication. The communication game is a kind of director-matcher task. Both the director and the matcher learn the same miniature artificial language – a mapping between meanings (typically an image) and signals (typically text), though they may not be exposed to all possible pairings, and the signals may be redundant or degenerate (many meanings may be linked with the same signal). **Stage 1:** The director is given a target meaning to communicate about, and must send a signal to the matcher. **Stage 2:** On receiving the signal, the matcher must guess which of the meanings the director intended to communicate about. **Stage 3:** Both the director and the matcher then receive feedback – seeing the intended meaning, the signal and the guessed meaning.

Either the experimental software or the computational program provides a framework in which these games happen. The individuals 'know' the rules of the game and what their behavior should be at each stage, and are cued when to act by the framework. In real life, however, there is no such framework that dictates the actions of individuals. However, human conversation does have norms which allow this kind of interaction to happen. Conversation Analysis is the study of these norms – a set of implicit rules, rights and responsibilities that speakers use in everyday conversation (see Sidnell & Stivers, 2012). Below we re-analyse the communication game in terms of these features.

2.1. *Turn Taking*

Human conversation takes place in a sequence of turns. Typically, one speaker will say something followed by another speaker, with speakers aiming to

minimise the amount of gap and overlap between each other's turns (Sacks, Schegloff & Jefferson, 1974). Features such as competition for taking a turn, and the possible negative interpretation of long pauses provide a pressure to anticipate turn endings in order to facilitate rapid transitions between turns. Speakers use a variety of systems such as gesture and hesitation markers for managing these turns.

In a communication game, each 'stage' can be thought of as a turn. Turn transitions and timing are handled by the experimental framework, meaning that participants do not have to decide who talks at what point, nor decide precisely the timing of their turns. Signals will never overlap, and in most cases have no temporal dimension, or are continuously available to participants rather than transitory. Therefore, the norms for negotiating turn timing cannot evolve, and cannot effect the general evolution of the language. Participants are aware of how long a participant takes to complete their stage, perhaps reflecting the amount of difficulty experienced by their partner, but it is currently untested whether this plays a part in their decision processes.

In real speech, the typical gap between two turns is only a few hundred milliseconds (Stivers et al., 2007), meaning that speakers must distribute resources between comprehending the current turn and planning their own next turn. This suggests that the structure of language must adapt to these cognitive demands (Levinson, 2016). For example, cognitive load may be greatest around the ends of turns, meaning there may be optimal distributions of information and redundancy in a signal (see Roberts & Levinson, 2015).

2.2. *Sequence oragnisation, noise and repair*

A series of turns which constitute a coherent exchange is called a 'sequence'. These include simple sequences such as a greeting followed by a greeting or a question followed by an answer. Kendrick et al. (2014) claim that all languages share a core set of these sequences which constitute a "universal infrastructure for action". That is, a necessary framework for having conversations. There are norms which govern the progression of these sequences, and the kinds of 'sub sequences' that can occur within them for repair or clarification. For example, if one interlocutor does not hear what was said they can launch a 'repair' sequence where they seek clarification about the prior turn, which the initial speaker can provide before returning to the main sequence.

In the iterated learning experiments, the experimental framework dictates what type of sequence the participants engage in, and what role each participant has at each point. A single 'game' is something like a recruitment sequence, with stage 1 being a request ("give me X"), stage 2 being something like granting the request or a pre-offer ("You want this?"), and stage 3 being

confirmation ("Yes, that's right" / "No, this one"). Participants are not able to initiate repair sequences.

3. Conclusion

Iterated learning experiments provide a rich paradigm for exploring how conversational interaction provides a framework that supports the evolution of structure in language. By manipulating parts of the communication game, it should be possible to investigate their impact on the evolution of structure. For example, instead of the experimental framework specifying the allocation and timing of turns, an 'open channel' could be used where participants could send continuous signals at any point and take any role at any point. Structures should emerge that mark pragmatic actions or points where turn transition is relevant, supporting or constraining the way referential signals are used.

In a similar way, a wider range of interactional options could be used to investigate the role of sequence organisation. Exactly what parts of the 'universal infrastructure for action' are necessary for bootstrapping a language? In Macuch Silva & Roberts (2016), we suggest that the introduction of noise in a typical communication game should provide a pressure for signals to be maximally distinct, creating a bias against simple compositional languages. However, our experiment added the ability for participants to initiate a simple repair sequence (the matcher asks the director to produce another signal before guessing). This counteracts the pressure from noise, allowing the emergence of compositionality. In this sense, repair is a crucial feature in the emergence of structure in language. We also found that participants used repair to request clarification. In one pilot case, participant A used a signal which only referred to part of the meaning ('pale',[shape]), B initiated repair and A upgraded their description to be more specific ('palekiki', [shape, colour]). This reveals to B how A conceptualises the compositional structure of the signal, thus helping them to converge on a compositional language.

It is also possible to explore how aspects of interactional infrastructure might have evolved in the first place. This is a harder question, since interaction is so basic to human behaviour, but clues may be found in the interactional systems of social animals (see Frölich et al., 2016). Ultimately, we must look at interaction - the nexus between processing, acquisition and evolution - if we are to arrive at an integrated understanding of language.

References

Claidière, N., Smith, K., Kirby, S., and Fagot, J. (2014). Cultural evolution of systematically structured behaviour in a non-human primate. Proceedings of the Royal Society of London B: Biological Sciences, 281(1797):20141541.

Dingemanse, M., & Enfield, N. J. (2015). Other-initiated repair across languages: Towards a typology of conversational structures. Open Linguistics, 1, 98-118.

Fröhlich M., Kuchenbuch P. H., Müller G., Fruth B., Furuichi T., Wittig R. M. and Pika S. (2016). Cooperative Communication And Communication Styles In Bonobos And Chimpanzees In The Wild: Same Same But Different?. In S.G. Roberts, C. Cuskley, L. McCrohon, L. Barceló-Coblijn, O. Feher & T. Verhoef (eds.) The Evolution of Language: Proceedings of the 11th International Conference (EVOLANG11). Available online: http://evolang.org/neworleans/papers/75.html

Kendrick, K. H., Brown, P., Dingemanse, et al. (2014). Sequence organization: A universal infrastructure for action. Talk presented at the 4th International Conference on Conversation Analysis. UCLA.

Kirby, S., Cornish, H., and Smith, K. (2008). Cumulative cultural evolution in the laboratory: An experimental approach to the origins of structure in human language. Proceedings of the National Academy of Sciences of the United States of America, 105(31):10681–10686.

Kirby, S., Tamariz, M., Cornish, H., & Smith, K. (2015). Compression and communication in the cultural evolution of linguistic structure. *Cognition*, *141*, 87-102.

Levinson, S. C. (2016). Turn-taking in Human Communication–Origins and Implications for Language Processing. Trends in cognitive sciences, 20(1), 6-14.

Macuch Silva, V. and Roberts, S. (2016). Language Adapts To Signal Disruption In Interaction. In S.G. Roberts, C. Cuskley, L. McCrohon, L. Barceló-Coblijn, O. Feher & T. Verhoef (eds.) The Evolution of Language: Proceedings of the 11th International Conference (EVOLANG11).

Roberts, S. G. and Levinson, S. C. (2014). Interaction constraints variation in linguistic structure. In Proceedings of the 4th International Conference on Conversation Analysis (ICCA14). Los Angeles, CA, USA.

Sidnell, J., & Stivers, T. (Eds.). (2012). *The handbook of conversation analysis* (Vol. 121). John Wiley & Sons.

Stivers, T., Enfield, N. J., Brown, P., Englert, C., Hayashi, M., Heinemann, T., Hoymann, G., Rossano, F., De Ruiter, J. P., Yoon, K.-E., and Levinson, S. C. (2009). Universals and cultural variation in turn-taking in conversation. Proceedings of the National Academy of Sciences, 106(26):10587– 10592.