SE367 – Project Report

Vidur Kumar (Y8560)

Development of Structure in Artificial Communication

Abstract

Language is essentially a structured signal space, which is mapped to a semantic space – to express it's meaning. But to begin with, the signal space is purely definable by the possible outputs of the instruments used to generate the signals (e.g. – vocal cords (sounds), arms (gestures), etc). The signals develops a structure when it used by numerous individuals – either due to a preference for certain types of signals (depending on the ease of producing them), or by convention, or by stable association to some semantic.

This study uses an artificial signal space of a symbolic nature (checker-patterns) to study the development of structure via iterative learning and if differences emerge when the semantic content is (or is not) associated with the signal space being transmitted from generation to generation.

Results replicate data from earlier studies – which indicate that signals converge and stabilize over generations of iterative learning. The effect of semantic content was not clear in the study – and due to lack of time and subjects, the experiment could not be redesigned to overcome logistical and analytical drawbacks.

Methodology

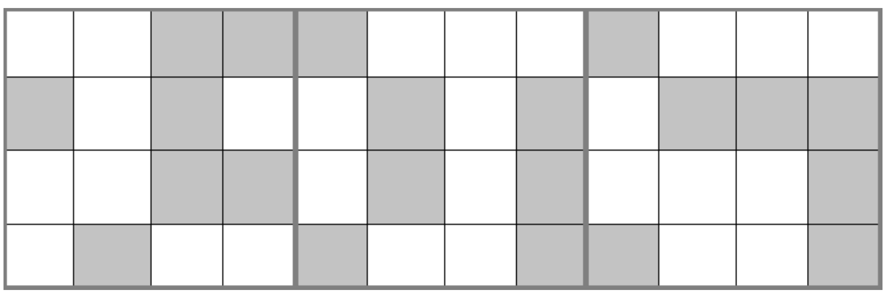


Fig.1 *A sample of one signal = three 4x4 checker patterns*

As per previous studies done on artificial communication (ref1, ref2), an artificial language was created for the purposes of study (Fig.1). Also, this study utilized the iterative learning methodology – as it is an accepted method to study the development of language – when it is passed on from one generation to the next.

Previous studies have used linguistic or pseudo-linguistic signal spaces, whereas in the current study – a more symbolic approach has been taken. This approach was adopted for its ease of quantification as it does not require image/wave-form analysis for comparison between two signals – simply the no. of changes of dark squares into light squares (and vice-versa) is a good enough measure. This approach might have negatively impacted the second part of the study – which focused on semantic involvement with the signal space (more in the Discussion section).

The first set of experiments replicate data from an earlier study (ref1) – which depicts cultural emergence of structure in the signal space – without semantic connection.

<u>Experiment 1</u>

- 18 random 4x4 checker-patterns were created and merged to form 6 starting signals. Also, 30 subjects were divided into 6 sets of 5 each, with each set starting with one of the 6 random signals.
- The first subject of a set was shown the respective set's starting signal for 15seconds. Then he/she was asked to replicate it on a blank file (in MS Paint).
- The output from the first subject was used as input for the next subject in the set, and so on.

The second set of experiments, was ideologically borrowed from (ref2) – where a semantic space of animated shapes was created and randomly assigned signals (generated separately). The subjects were trained on the a part of the randomly mapped semantic and signal space – and then asked to provide signals for the whole semantic space. The iterative learning procedure was carried out for 2 subject-groups of 3 each – to observe any changes from the earlier experiment – due to the involvement of semantic content.

Experiment 2

- 18 animations were made as .gif files, depicting 3 types of motion between a circle and a square, each having one of three colours (red, blue, green – not repeated). Each animation was randomly assigned a 3x9 checker pattern signal (to reduce complexity of signal to be remembered). These were then divided into 6 sets of 3 animations (Set1 to Set6).
- The first subject of a group was trained on two Sets of animations (6 animations) – given 3 minutes with each of the three animations on display, alongside the assigned signals – with freedom to replicate them as desired.
- Then asked to provide signals (as checker patterns) for all six Sets (18 animations).
- Two of the Sets (with their newly assigned signals) were then used for the training of the next subject in the group, and so on.

Results and Discussion

The results of the two experiments were as follows –

Experiment 1:
The results replicated those of studies done earlier (ref1), showing the development structure in a randomly generated signal space, due to iterative learning across generations. The output signals were seen to retain certain basic features from input signals, and there were cases of mirroring of the features as well (Fig 2)

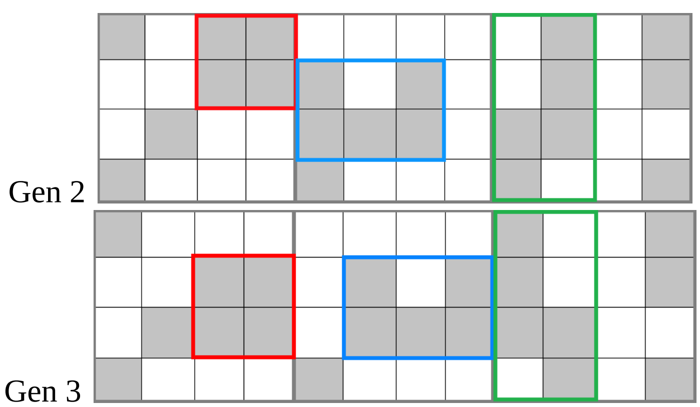


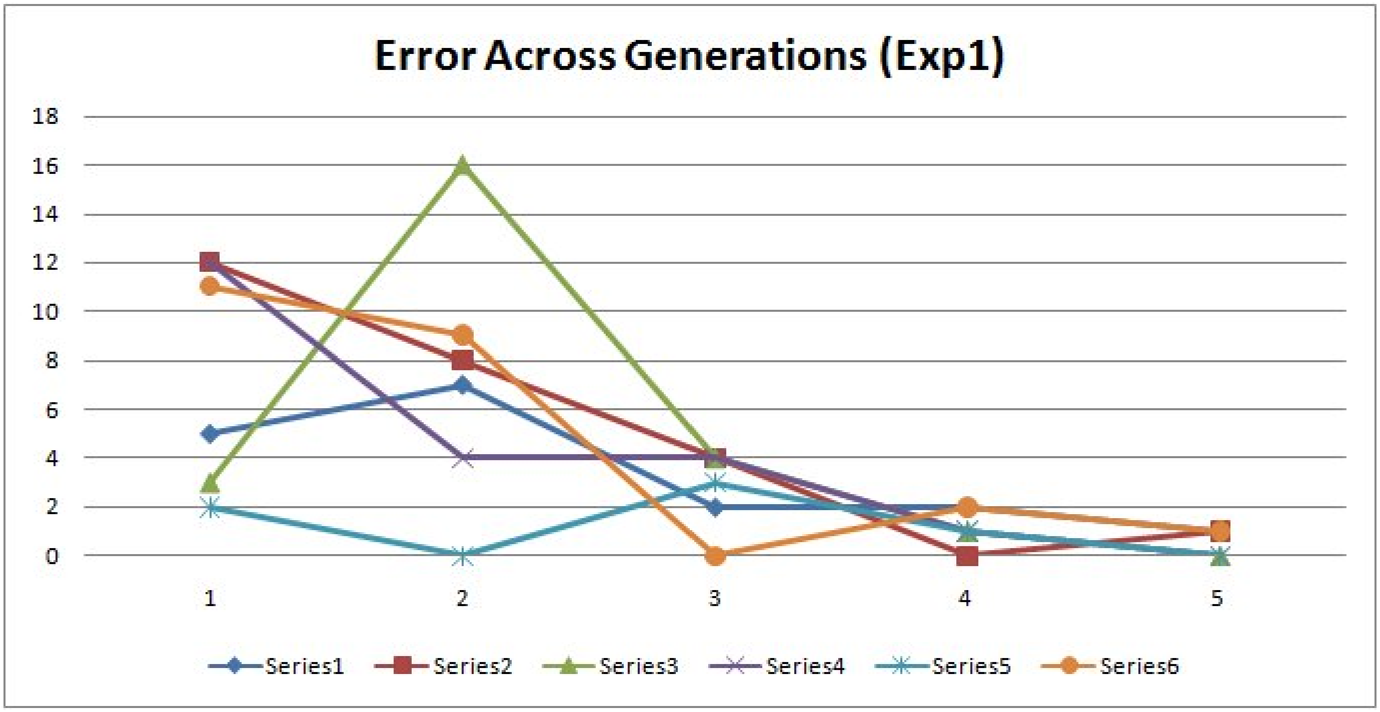
Fig.2 *Red and Blue outlines depict features retained (but shifted) in the output of consecutive generations. Green outline depicts mirroring of a feature between the outputs.*

Of the 6 groups studied, their inter-generational differences were as follows (Table 1), and the chart for the same (Fig. 3)

Table 1 *The inter-generational difference in signals from subjects of Experiment 1.*

Group	A	B	C	D	E	F
Gen 1	5	12	3	12	2	11
Gen 2	7	8	16	4	0	9
Gen 3	2	4	4	4	3	0
Gen 4	2	0	1	1	1	2
Gen 5	1	1	0	0	0	1

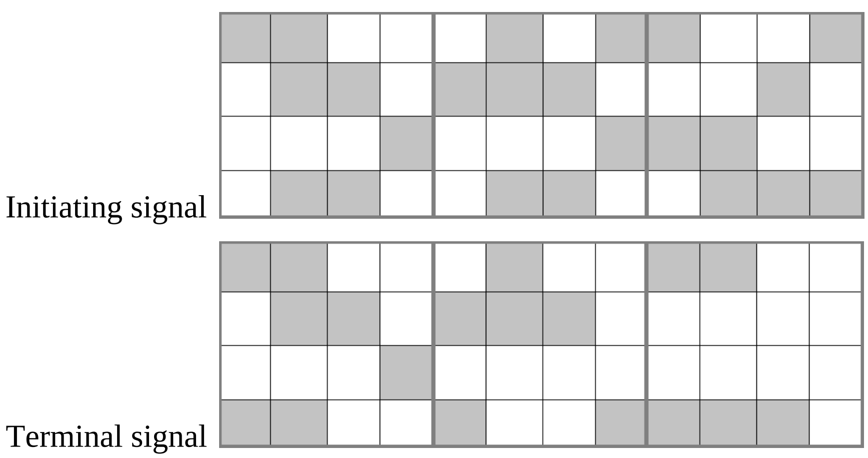
Fig.3 *Chart for Table 1(representing inter-generational difference, in Experiment 1)*



All groups displayed a downward moving graph for error across generations, as the signal was simplified and codified into easier to remember chunks (ref2) – making the transmission of the signal that much easier for the next generation. (data beyond 5th generation was not collected due to logistical reasons of lack of subjects – and expected redundance of data).

In general, the final outputs at the end of stabilization of signal were of lower detail than the initiating signals (Fig.4).

Fig.4 *Difference between complexity of Initiating verses Terminal Signals of a Group.*



Some of the data was anomalous, such as that of group E (Series 5) – where the signal stabilized very quickly and without much error. This is attributed to unforeseen structure being over-prevalent in the starting signal – making it very similar to the end results of the other groups, in terms of ease of remembrance.

However, all the other groups went through a phase of great alteration at some stage which resulted in a more stable signal structure as output.

Experiment2:
Experiment two did not have any consistent or meaningful results. Due to a shortage of subjects, only groups of 3 subjects could be formed – which did not allow for much scope in terms of convergence of the signals. But other factors were found to be responsible as well.

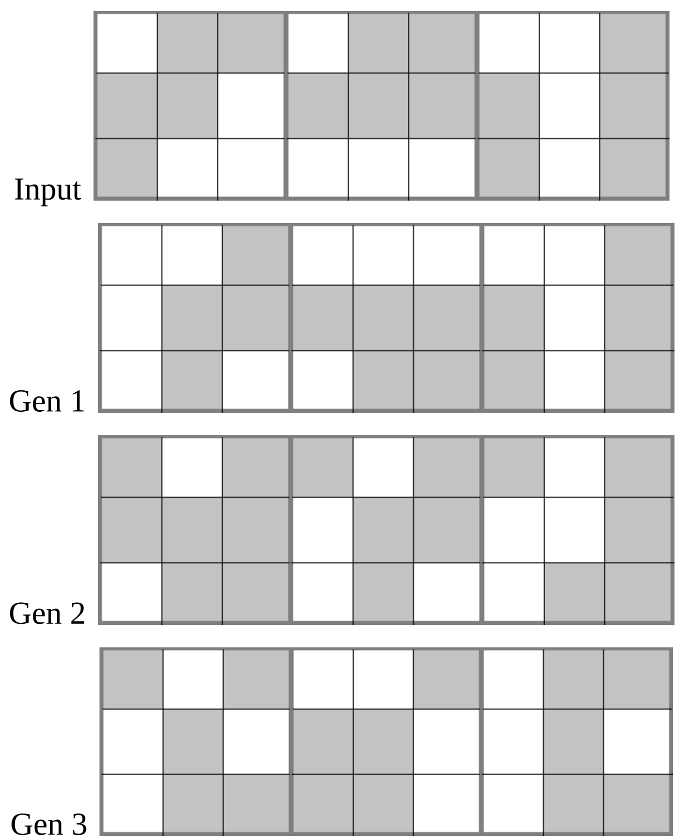
Also, even with the choice of a lower complexity signal space (3x9 instead of 4x12) there was no indication of convergence in the outputs of the subjects. Upon further discussion – it was found that the presence of semantic content confounded the otherwise simple task of simplifying the signal for ease of remembrance. Subjects admitted to trying to find best possible fitting "features" in the given signals (in association with the animations) – so as to accurately satisfy characteristics (such as colour or motion) in all relevant animations.

But with the description of unknown data being required – subjects hesitated from reducing the amount of data in the signals (which was done earlier to simply the task of remembrance) – thinking that they might have missed out some pattern that could have been present. Hence, they generated signal data from the possible random combinations available – to compensate for the 'smaller' features they had identified. This resulted in an influx of randomness at each generation – and thus did not lead to a converging trend for the signals.

Although the data allowed for the qualitative understanding that the core features were being retained – but their order in the 3x9 matrix, and the additional noise subjects created around them to maintain high data concentration – did not allow for any feasible quantitative analysis.

An sample of signals for one of the animations is shown in Fig.5

Fig.5 *Sample of signals generated in Experiment 2, for a given animation.*



In conclusion, the study was able to successfully replicate the earlier finding of Dr. Simon Kirby – with the changed context of symbolic signals instead of syllabolic ones. Though it may be argued and linguistic language is closer to our cognitive process than the symbolic form – this study does assert that the symbolic form of language can also be used for language structure studies – although the exact glyphs used might need some alteration to be compatible with quantitative analysis as well being less heavy on the working memory.

The effect of semantic content was not clearly seen in the experimental results – and the hypothesis that semantic content would lead to faster stabilization (in terms of no. of generations required to minimize error) than in the non-semantic context – did not get substantiated.

References

1. Simon Kirby, Tessa Verhoef , Carol Padden : **"Cultural emergence of combinatorial structure in an artificial whistled language"**, CogSci 2011.
2. S. Kirby et. al. **"Cumulative cultural evolution in the laboratory: An experimental approach to the origins of structure in human language".**PNAS _ August 5, 2008 _ vol. 105 _ no. 31 _ 10681–10686