Efficient coding in speech sounds: Cultural evolution and the emergence of structure in artificial languages

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Appendix A: Scribbles

A.1 Instructions

Experiment: Scribble2Sound

Welcome!

This experiment is conducted in the context of a research project on the evolution of speech at the Amsterdam Center for Language and Communication (University of Amsterdam). Thank you very much in advance for your participation! Please read this short instruction carefully before you start the experiment. If you have any questions or comments, don’t hesitate to let the experimenter know or contact t.verhoef@uva.nl afterwards.

The application you will start in a minute contains a ‘Scribble area’ and a ‘Topic area’. The scribble area allows you to produce scribbles that will be transformed into sounds. The topic area will display different pictures that have a specific sound connected to them. First, you will get some time to practice by drawing some shapes in the scribble area to find out how it relates to the sounds. It is important that you familiarize yourself somewhat with the scribble area. After this you start the experiment. During the actual experiment you are going to learn these specific combinations of pictures and sounds and at the same time you will learn to imitate these sounds using the scribble area.

In the training phase, you will hear a sound, see the corresponding picture and are asked to reproduce it by drawing a scribble. Try your best to make your own produced imitation resemble the example sound as closely as possible. This is not an easy task! So, please do not get frustrated! A colored border surrounding the topic will indicate how close your imitation was: the greener, the better.

In the test phase, you will only see the picture and are asked to produce the corresponding sound with a scribble. There will be a total of three rounds of training and testing, with short breaks in between.

Good luck!

Figure A.1.1: Written instructions given to participants in the Scribble to Sound experiment (described in chapter 3).
A.2 User interface

Figure A.2.1: Screenshot of the user interface for the Scribble to Sound experiment (described in chapter 3).
A.3 Random scribble trajectory generation

To create the initial set of sounds that were given as input to the first participant in each chain of the scribble to sound experiment (described in chapter 3), the computer generated random trajectories. These trajectories were transformed into sound using the same scribble to sound mapping that was used in the rest of the experiment. The trajectories were not entirely unconstrained, so that they sounded as if they could have been created by a person controlling the mouse.

Points on the trajectories are x, y pairs that represent locations in the two-dimensional scribble area where x and y are values between 0 and 1. For the first point of a random trajectory, a uniformly distributed random value inside the scribble area is chosen for both x and y. Then, the choice of each next point is constrained, so that it (1) is not too far away from the previous point and (2) creates a line between the current point and the previous point that has a large enough angle with the line between the previous point and its predecessor.

(1) The new point is chosen such that the new x value is \( x + \alpha \), where \( \alpha \) is a uniformly distributed random value between -0.025 and 0.025, with the additional constraint that it stays within the scribble area. The new value for \( y \) is computed in the same way and the new location needs to have a valid angle, determined as follows:

(2) The angle is computed by using the definition of the dot product of two vectors. The angle (\( \theta \)) between two vectors can be computed as:

\[
\theta = \arccos\left( \frac{\mathbf{A} \cdot \mathbf{B}}{\|\mathbf{A}\| \|\mathbf{B}\|} \right)
\]  

\( \mathbf{A} \) is a vector representing the line between the current point and the previous point, \( \mathbf{B} \) is a vector representing the line between the previous point and its predecessor, \( \mathbf{A} \cdot \mathbf{B} \) is the dot product of \( \mathbf{A} \) and \( \mathbf{B} \), \( \|\mathbf{A}\| \) is the magnitude of \( \mathbf{A} \) which is the Euclidean distance between the current point and the previous point and \( \|\mathbf{B}\| \) is the magnitude of \( \mathbf{B} \) which is the Euclidean distance between the previous point and its predecessor.

The angle is considered to be valid if it is larger than \( \frac{3}{4} \pi \).