Abstract

Humans and many other animals exhibit communicative behavior. One of the most important features distinguishes human beings from other animals is the extensive use of symbols in communication. The lack of evolutionary continuity between human symbolic communication and non-human animal communication makes the evolution of symbolic communication a puzzle.

Following the discovery of mirror neurons in the brains of humans and some non-human animals, a mirroring mechanism based on the neural activity related to the mirror neurons provided a solution to the evolutionary puzzle of symbolic communication. However, the functional role of mirroring in symbolic communication had not been understood yet. In fact, previous works found no empirical evidence for a functional link between mirroring and the performance of symbolic communication.

The present work aims to clarify the role of mirroring in symbolic communication. Specifically, this study hypothesized that mirroring plays a functional role in the formation of symbolic communication systems on the connotative level, rather than the denotative level. In order to investigate the neural activity in the formation of symbolic communication systems, this study designed an experiment adopting the experimental semiotics approach.

In the experiment, pairs of participants need to cooperate in a coordination game, in which the players need to develop communication systems with geometrical figures. Forty participants were recruited for the experiment. Participants went through a non-communicative condition individually and a communicative condition in pairs. During the experiment, the participants' neural activity was recorded by electroencephalography. Behavioral performance on forming symbolic communication systems was measured by three indices. These indices measure overall performance, the performance on the denotative level, and the performance on the connotative level, respectively. The mirroring activity was measured by the significance of mu-band power suppression in the electroencephalography (EEG) signals.

The first analysis compared the behavioral performance of the participants with significant mirroring activity in the communicative condition against those who showed significant mirroring in the non-communicative condition only, but found no significant difference. The second analysis found that the participants with significant mirroring activity in both

communicative and non-communicative conditions performed significantly better than the other participants in terms of overall performance and the performance on connotative level.

These results are consistent with the hypotheses of this study and suggest two potential benefits from mirroring for forming symbolic communication systems. Firstly, mirroring has immediate benefits for developing connotative meanings in symbolic communication. Secondly, mirroring has fundamental benefits for sharing arbitrary form-meaning mappings through interpersonal interaction.

In conclusion, the present study provided empirical evidence for a functional role of mirroring in the formation of symbolic communication systems, especially on the connotative level. The mirroring may have evolved in humans to respond to imagined action without actually perceiving it. This extended mirroring may provide a neural substrate for developing and sharing symbolic communication systems, by which humans become capable of sharing knowledge beyond the limits of space and time.

Keywords: Mirroring, Symbolic communication, Electroencephalography, Experimental semiotics, Communicative coordination game, Mu-suppression.