REPETITIVE MUTUAL HYPOTHESIZING INDUCES CHANGE OF SYMBOL SYSTEMS IN GRAPHICAL COMMUNICATION

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We conducted a graphical communication task to examine what kinds of devices are effective for communication to tell what the partner does not know. During the task, the sender and receiver mutually formed hypotheses about the partner's intentions to correct misunderstandings. Repetitive interaction facilitated the frequent changes of drawings and caused the change of symbol system from iconic to figurative.

1. Introduction

Our ancestors seemed to have abilities to form primitive symbol systems, compounded mainly of indexical and iconic association (Bickerton, 2003). Assuming Bickerton's view that the emergence of symbolic representation had been primarily a cultural rather than a biological event, the interaction between senders and receivers during symbol communication must be an important factor in shaping sophisticated symbol systems. Such systems would have included arbitrary symbols and figurative expressions, and that make us possible to tell displaced events or novel objects. In this study, we aim to reveal the process of interaction during symbol communication in that the sender tells what the receiver does not know. Such a communication seems to be unique to human beings, and advantageous to acquiring and sharing new knowledge.

We designed an experiment to investigate how such symbol communication is realized based on the graphical communication task used in Fay et al. (2003). In graphical communication, a sender conveys an assigned task to a receiver by drawing. Communication through drawings enables us to observe what kinds of devices that the sender adopts to convey their intentions.

2. Graphical communication experiment

Drawings function as an "iconic" symbol system because the outline of an object can be a symbol indicating the object through similarity. The meanings of

nouns for objects with particular shapes, especially, can be easily conveyed by drawing their outlines. In contrast, the characteristics of the objects (such as adjectives) cannot be conveyed directly through particular shapes; hence, alternative ways other than drawing outlines need to be devised to express such meanings. We compared two tasks: one in which an adjective could not be easily guessed in association with a noun, and the other in which it could

a. **Unknown** task: An **unfamiliar** combination of an adjective and a noun (e.g., Sour fire, Soft traffic light)
b. **Known** task: A **familiar** combination of an adjective and a noun (e.g., Sour apple, Soft pillow)

Unknown task corresponds to communication to tell what the receiver does not know.
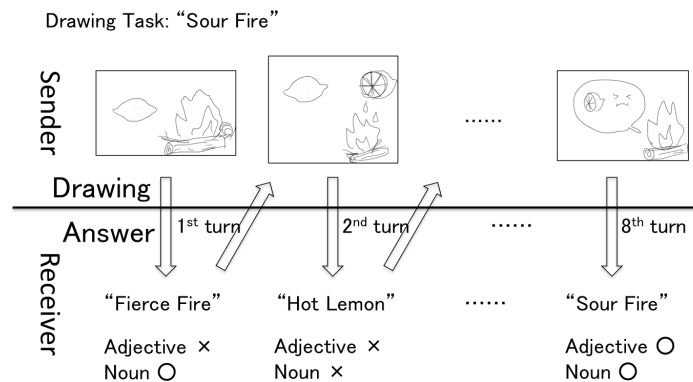
Drawing Task: "Sour Fire"

Figure 1. The flow of graphical communication experiment. The example of "sour fire."

In the experiment, two participants were paired: their roles were to be either a sender, expressing assigned tasks through drawings, or a receiver, identifying the references to the drawings by answering with a combination of an adjective and a noun. The sender redrew according to the receiver's answer. This process, drawing and answering, called a turn, was repeated eight times (Fig. 1). A questionnaire about participants' intentions during the tasks was conducted to analyze the process in detail. We used the data to interpret the sender's drawings and the receiver's understandings.

Thirty-six Japanese graduates (18 pairs) participated in the experiments. The pairs communicated using tablet PCs in separate rooms so that they would not be able to use other communicative media such as verbal exchanges and eye contact. The use of linguistic characters and symbols, such as the alphabet, *kana*, and algebraic signs, to extend non-arbitrary sign meanings was prohibited in the drawings. Participants were instructed that the drawing task was composed of a

simple adjective and a noun, but not told that what kind of combination they were. Receivers were allowed to answer words other than adjectives and nouns or "don't know" only when they could come up with nothing.

3. Analysis of interaction

In this experiment, the receiver makes some hypotheses about the object that the sender tries to express by interpreting the drawing, and conveys the interpretation as an answer. By interpreting the answer, the sender also makes hypotheses about the receiver's understanding of the object and draws a new picture based on the hypotheses. Through the repetition of such interaction of mutual hypothesizing, the sender and receiver constitute a symbol system to communicate what the receiver does not know.

Receivers formed at least two hypotheses; one is about the noun, and the other is about the adjective. They often misunderstood the senders' drawings especially in unknown tasks, because the nouns did not have the usual features of adjectives in unknown tasks. Thus, repairing the receivers' misunderstandings is more difficult in unknown tasks than in known tasks. The repairing did not always achieved within one or two turns because the pair had to co-create a symbol system at the same time. Receivers often became aware of senders' intentions some turns later.

The sender tried to repair the receiver's misunderstandings by redrawing based on receiver's answers. To try to correct the receiver's understanding, the sender usually changed (or added) objects to draw or the structure of drawings. No change of drawing could be a sign of correct answer for the receiver. The receiver also tried to repair his/her understandings to more reasonable (usually, more natural) one. Some receivers could request repairing by answering "don't know" or presenting several alternatives to show his/her understandings.

The repairing process facilitated the frequent changes of drawings. We found that the senders mainly used two types of expressions:

Metaphoric expression: refers to the features of an object in terms of another object that typically has the feature (exemplified by a lemon in Fig. 2),

Metonymic expression: refers to the features of an object in terms of motion including facial expression, which is adjacent to that feature (exemplified by a motion of "eating" in Fig. 2).

We classified all drawings into four groups according to the use of these two types of expressions: Only metaphoric (Metaphor), Only metonymic (Metonymy), both metaphoric and metonymic (Both), and Neither metaphoric

nor metonymic (None). In addition, we divided all drawings into four groups, the drawings of the pairs who answered the correct adjective (Correct pair) or incorrect adjective (Incorrect pair), and in first half (1-4 turns) or in last half (5-8 turns) and made contingency tables of unknown tasks and known tasks (Table 1).

Table 1. Contingency table of unknown tasks and the results of residual analysis.
▲: significantly larger, ▽: significantly smaller, $p<.05$

	Metaphor	Metonymy	Both	None
Correct pair in first half	4	0 ▽	2	5
Correct pair in last half	2	4	12 ▲	7
Incorrect pair in first half	14	26 ▲	4 ▽	17
Incorrect pair in last half	10	12	19 ▲	6 ▽

The result of a Fisher's exact test showed that there was a skew in unknown tasks ($p<.001$) but not in known tasks ($p=.380$). The number of drawings of the Both type was significantly larger in the last half of the eight repetitions in unknown tasks (Tamura & Hashimoto, 2014), thus, the use and interpretation of drawings became figurative. Besides, the result of residual analysis showed that the number of Metonymy type in the first half was significantly smaller in the pairs who answered correct adjectives than the pairs who answered incorrect adjectives (Table 1). This result suggests that increasing the combined use of metaphoric and metonymic expressions is a common strategy, but starting the frequent uses of only metonymic expression may cause receiver's misunderstandings in unknown task.

4. Case analysis

Here we show two example cases of an unknown task "sour fire." A sender drew a picture of a man eating a fire (upper drawings in Fig. 2) in the first half. The picture of "a man eating a fire" was used metonymically to express "sour" by the sender based on common experience that the motion "eating" is adjacent to the taste of "sour." The receiver's hypothesis about the noun was "fire" and was correct throughout the first four turns while the hypotheses about the adjective were not correct and changed in each turn. The receiver iconically interpreted the sender's drawings and answered "not-hot fire" in the third turn and "edible fire" in the fourth turn.

The receiver changed his hypothesis about the noun in the fourth turn and answered as "a man who got burned," which seemed more natural because fire

is neither edible nor sour. To try to correct this mismatch, the sender added a metaphoric expression (a picture of a lemon and other sour objects) aside the metonymic expressions (three drawings lower right in Fig. 2). However, the receiver did not change the hypothesis about the noun and answered "a man" as the noun in the last four turns. He interpreted the picture as "a hungry man" in the sixth and the eighth turns.
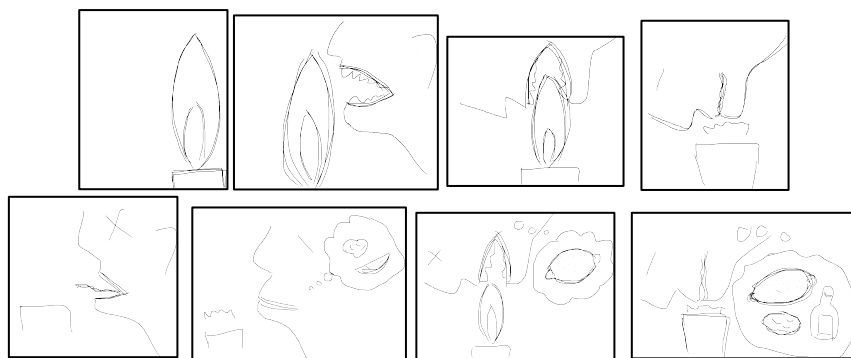

Figure 2. Example of the changes of drawings. The drawings for an unknown task "sour fire" at the first half (upper, 1-4 turns from left to right), and last half (lower, 5-8 turns from left to right).

In another example, a sender drew a picture of a lemon and a fire in the first half (the upper drawings in Fig. 3). The picture of a "lemon" was used metaphorically to express the feature "sour" by the sender while the receiver interpreted it as a noun in the second and the third turns. He answered "a hot lemon" based on natural understanding.

Figure 3. Example of the changes of drawings. The drawings for an unknown task "sour fire" at the first half (upper, 1-4 turns from left to right), and last half (lower, 5-8 turns from left to right).

To try to correct this mismatch, the sender adopted a thought bubble to make the receiver understand that a fire denoted the noun. This change was

gradually understood by the receiver, and he changed the hypothesis about the noun into a "fire" in the fourth turn, although he could not form a hypothesis about the adjective and, therefore, answered "don't know." In this case, the receiver answered correctly after the sixth turn (three drawings in the lower right of Fig. 3), where the sender added metonymic expressions aside the metaphoric expressions.

The metaphoric expression in the second example was interpreted as a conceptual metaphor (Lakoff & Johnson, 1980), where a target concept is understood by a mapping from a source concept. When the sender started from only metaphoric expression and then used the both metaphoric and metonymic expressions, the source-target mapping may be more easily understood by the receiver. The thought bubbles in these examples can be considered a kind of convention to distinguish the noun and the adjective. The sender and the receiver created this convention through interactions. This convention seems to help to identify the direction of mapping between source and target concept when the conceptual metaphor was noticed by the receiver.

5. Conclusion

This study shows that the combination of metaphoric and metonymic expressions is a common device to tell what a partner has not known in graphical communication. We think, however, that combinatorial use of figurative expressions from the initial stage is not useful to convey what the partner does not know, as the intention of sender and the understanding of receiver should coincide for figurative expressions to be correctly interpreted. From the case analysis, the uses of only metonymic expression from the beginning seemed to cause receiver's subsequent misunderstandings in unknown task. The convention like a thought bubble may help the understanding of conceptual metaphor. The process of mutual hypothesizing is required for reaching the agreement. This process facilitates the sequential changes of drawings and their interpretations and leads to the change of symbol system from the initially iconic one to the figurative system.

References

Bickerton, D. (2003). Symbol and structure: a comprehensive framework for language evolution. In M. H. Christiansen and S. Kirby (Eds.), *Language*

evolution (pp. 77-93). Oxford: Oxford University Press.

Fay, N., Garrod, S., Lee, J., Oberlander, J. (2003). Understanding interactive graphical communication. *Proceedings of the 25th Annual Conference of the Cognitive Science Society*, Boston, MA.

Tamura, K. & Hashimoto, T. (2014). Symbol extension and meaning generation in cultural evolution for displaced communication. *The Evolution of Language: Proceedings of the 10th International Conference*, pp. 326-333.

Lakoff, G. & Johnson, M. (1980) *Metaphors We Live By*. Chicago: University of Chicago Press.