How Communicative Efficiency and Speaker Social Cognitive Ability Shape Silent Gesture Production

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Human communication is optimized for interaction and understanding (Gibson et al., 2019; Goldberg & Ferreira, 2022). This suggests that human language evolves into a way so as to allow easy, rapid and robust communication (Conway et al., 2020; Hahn & Xu, 2022), and language users actively adapt communication to maximize the rate of communicative success while minimizing the effort in both oral modality (Mahowald et al., 2013; Rubio-Fernandez et al., 2021) and manual modality (Rasenberg et al., 2022; Slonimska et al., 2020). However, it remains unclear whether communicative efficiency plays a role in the process of language creation. Does communicative efficiency influence individuals' choices when they create a novel communication system?

To answer this question, we focus on the rudimentary communication system created in manual modality – silent gesture. Silent gesture is gesture-based communication system created by hearing speakers when communicating exclusively in manual modality. Building upon iconicity, gesturers communicate using silent gesture without pre-established form-meaning mapping by employing iconicity in various ways. Previous cross-linguistic studies have demonstrated systematic iconicity in silent gesture (Ortega & Özyürek, 2020a, 2020b). To express a given concept, gesturers reliably employed the specific gesture with a subtype of iconicity (e.g., gesturers prefer to use a gesture that pantomimes eating an apple, rather than any other gesture form, when depicting an apple). The mechanism that underlies the observed systematic iconicity remains unclear. The presents study focuses on communicative efficiency as a factor that determines which subtype of iconicity is employed. We propose that individuals select silent gestures by comparing the communication efficiency of different options and producing gestures that could maximize the probability of being understood while minimizing the effort. Furthermore, we predict that individual socio-cognitive ability influences the accuracy of a hearing speaker in estimating and comparing the communicative values of different silent gestures.

In Experiment 1, we investigated whether hearing speakers are more likely to produce silent gestures that maximize meaning recoverability. To minimize the impact of production cost, we approximated the cost based on the number of gestures produced and focused on comparing the communicative value of individual gestures. To encourage participants to produce a single gesture for each target word, they were allotted 4000 ms to generate the gesture in response to each stimulus. For each concept, we identified the dominant gesture (i.e., the most frequently used gesture produced by more than 50% of participants) and the non-dominant gesture (i.e., the second most frequently used gesture). The dominant and non-dominant gesture forms for the concepts were then shown to 96 comprehenders, who were asked to provide their best guess for the meaning of each gesture. To measure the communicative efficiency of a gesture form, we used the Shannon entropy, which measures the informativeness of the gesture form (i.e., how consistent interpretations are across comprehenders), and the semantic relatedness, which represents the average semantic distance between the interpretations and the target word for the gesture. We used Global Vectors for Word Representation (GloVe) to quantify semantic similarity. The semantic relatedness of a particular gesture form is assessed as the mean semantic similarity between interpretations that were provided by a group of comprehenders, and the target word used to elicit the gesture. As shown in Figure 1, comprehenders were more likely to provide consistent and semantically related interpretations to the target word when interpreting a dominant gesture than a non-dominant gesture.

Experiment 1 also revealed individual differences; that is, some participants often used non-dominant gestures, which are less communicatively effective. To further explore this phenomenon, we conducted Experiment 2 to investigate whether hearing speakers produced less communicatively efficient gestures due to their inability to accurately estimate the communicative values of candidate gestures. In addition, we examined the association between an individual's socio-cognitive ability and the accuracy of their estimations of gesture communicative value. The study consisted of 79 native English-speaking adults who produced gestures for the same set of concepts as Experiment 1. Participants were subsequently asked to estimate the communicative value of the gesture forms that the participants in Experiment 1 had produced for each concept, and their socio-cognitive abilities were assessed through the administration of the Empathy Quotient (Baron-Cohen & Wheelwright, 2004).

Our results indicate that hearing speakers tended to rate gesture forms they produced in the production phase as more communicatively efficient than the hearing speakers who did not produce the gesture form. We further calculated how precisely each participant estimated communicative value of gesture forms, using item-by-item correlation between the participant's estimated communicative value (rated on a 7-point Likert scale, e.g., "How well do you think the addressee could understand the meaning of this gesture?"; a larger value indicates a higher estimated communicative value) and the actual entropy (i.e., uncertainty of a gesture form, based on the data from Experiment 1; a lower value indicates a higher communicative value), for all the gesture forms. The magnitude of the item-by-item correlation coefficient, as depicted on the y-axis in Figure 2, increases (i.e., get closer to -1) when participants provide more accurate estimates. As shown in Figure 2, participants with lower empathy scores were less accurate in estimating gesture communicative values than those with higher scores.

Taken together, our results indicate that communicative efficiency and individuals' socio-cognitive ability play a role in individuals' choices of iconic form to convey a particular concept when creating a novel communication system.

Index Terms: silent gesture, communicative efficiency, empathy

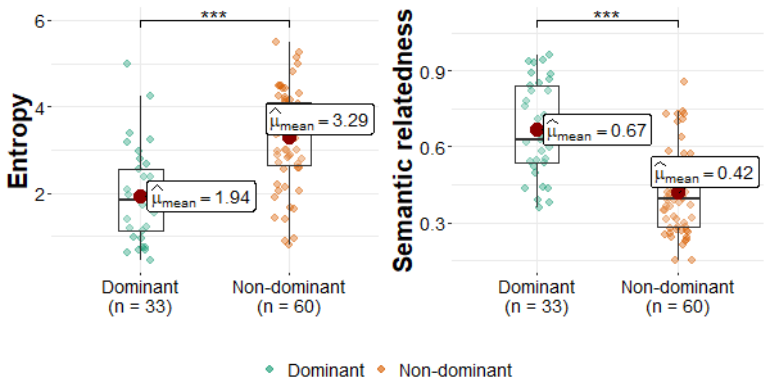

Figure 1: *Distribution of entropy (Left) and semantic relatedness (Right) of gesture forms based on their production probability. Each dot represents a gesture form.*

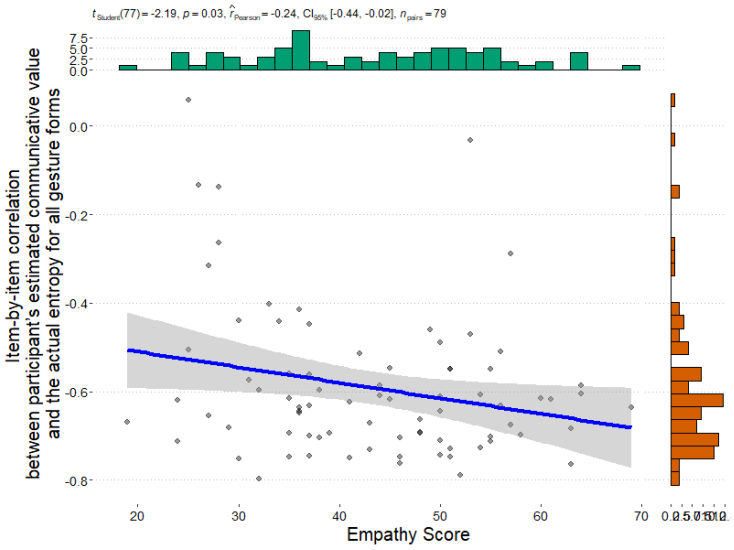

Figure 2: *Correlation between individuals' accuracy in estimating gesture communicative value and their Empathy Quotient score. Each dot represents a participant. Y-axis represents item-by-item correlation between a given participant's estimated communicative value and the actual entropy for all gesture forms. The higher value along the y-axis indicates that the participant estimated the communicative value for comprehenders better.*

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