Systematicity in gesture production, perception may support sign language emergence

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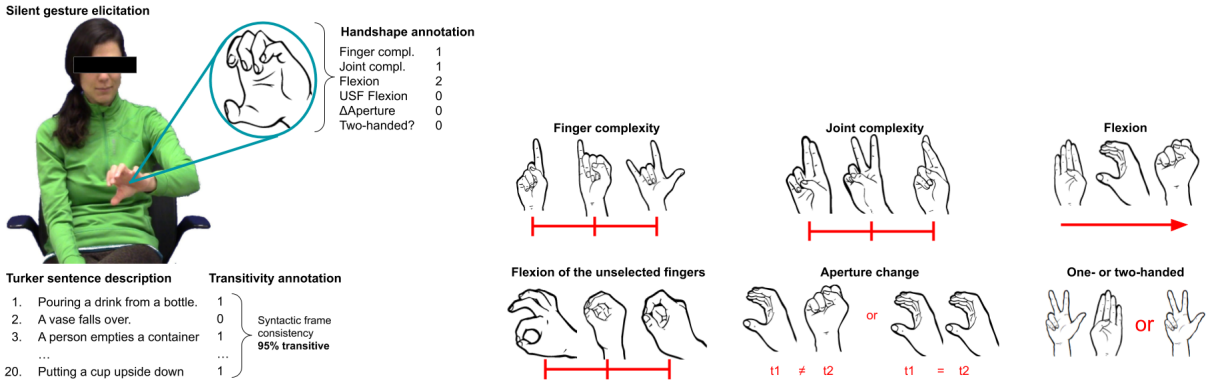
When communicating in a new medium, like silent gesture, people must adopt novel strategies to ensure successful communication. It has been argued that initial productions are inconsistent and unstructured, with systematicity emerging through interaction and transmission (Motamedi et al., 2019). In support, studies on sign language emergence have shown that homesigners, and signers of young and established sign languages systematically vary handshape to code transitivity in production, but gesturers do not (Brentari et al., 2017). However, perception studies show that non-signers can resolve abstract syntactic-semantic information, like distributivity, telicity, and phi-features (Marshall & Morgan, 2015; Strickland et al., 2015; Schlenker & Chemla, 2018) from gesture and sign on first exposure, suggesting that some aspects of the visual signal are immediately analyzable. Further, the recurrent emergence of handshape as a transitivity marker across unrelated sign languages suggests that this strategy is systematic. To reconcile these disparate findings, we conducted silent gesture production and perception experiments. We modeled handshape to uncover specific visual aspects of the signal that may undergird transitivity categorization.

Methods: We elicited silent gestures from 6 non-signing participants who portrayed 46 unique events involving the manipulation (transitive) or movement (intransitive) of a variety of objects (6*46=276 gestures). Gestures representing transitive events were considered transitive, otherwise intransitive (*inherent transitivity*). Next, we collected 20 descriptions of the meanings of these gestures from 95 non-signers on Amazon Mechanical Turk (Turkers; 276*20=5,520 sentences; Fig. 1a). Gestures were annotated for 6 handshape features, each linked to transitivity marking in sign languages (Fig. 1b). We then labeled the sentences for transitivity (1='transitive'). A gesture was considered transitive if its proportion of transitive responses was greater than the median proportion of all transitive responses, otherwise intransitive (*perceived transitivity*). We performed two analyses: We trained linear support vector classifiers to predict (1) whether a given gesture is inherently in/transitive and (2) whether it is perceived in/transitive. In each analysis, we used a 6-fold leave-one-out paradigm: The data were randomly split into 6 partitions, trained on 5 of the partitions and tested on the 6th, producing an accuracy score. This was repeated 6 times, such that each partition was the test set once. We computed mean accuracy and compared it against chance using the probability mass function of the binomial distribution. Finally, we averaged the weights for each predictor across all 6 folds in each analysis to assess handshape parameter importance.

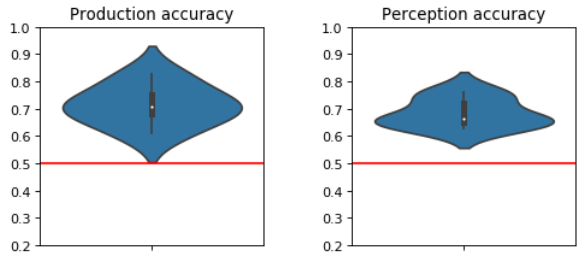
Results: Turkers were 91.3% accurate at guessing the transitivity of the gestures (chance=50%, $p<0.001$). Likewise, classifiers trained on production and perception data were equally good at predicting the inherent and perceived transitivity of the silent gestures: 71.38% and 73.91% accurate, respectively ($p<0.001$; Figs. 2a,2b). Three handshape features characterized both the production and perception of transitivity distinctions. Further, these features had the same relative weighting: *One- or two-handed* $>$ *Flexion* $>$ Finger Complexity (Fig. 2c).

Interpretation: Non-signers produce transitivity cues that are perceived accurately by other non-signers. This suggests that transitivity contrasts are more systematic than previously assumed, even in absence of a communicative history (interaction, transmission). Specifically, handshape features predict a significant amount of both the production and perception of transitivity distinctions across a diversity of events, indicating handshape variation as a general strategy for transitivity marking in gesture. Further, the same handshape features are informative in both production and perception, with the same relative weighting, consistent with the high interpretation accuracy observed. We suggest that transitivity contrasts in gesture involve the recruitment of stored representations subserving manual action production and perception (Rumiati et al., 2010), and that these representations may then be repurposed to mark transitivity contrasts in emerging sign languages.



(a) (b)

Figure 1: (a) **Experimental design:** An inherently transitive gesture, depicting *Someone put a book on its side*, with Turker response sentences annotated for transitivity. Handshape was annotated for features in (b); (b) **Handshape features:** 'Finger complexity' & 'Joint complexity' = measures of ease of articulation w.r.t. fingers and joints (each scored 1 to 3); 'Flexion' = degree of curvature of the profiled fingers (1 to 6); 'Flexion of unselected fingers (USF flexion)' = degree of curvature of the backgrounded fingers (-1 to 1); 'Aperture change' = whether the hand opens/closes (categorical); 'One- or two-handed' = whether the production involved one or two hands (categorical).



(a) (b)

	Production	Perception
Fing. compl.	0.503	0.124
Flexion	0.822	1.025
USF flex.		0.296
ΔAperture		-1.773
Two-handed?	1.187	1.303

(c)

Figure 2: Violin plots showing distribution of classifier accuracies for the production (a) and perception (b) analyses. Red line indicates chance in both. (c) Average model coefficients for the best predictors. Three were most informative for the production analysis, five for the perception analysis. Positive values correspond with 'transitive' items. Some features, like 'Joint complexity' had near-0 weights (uninformative) and were omitted.

References

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