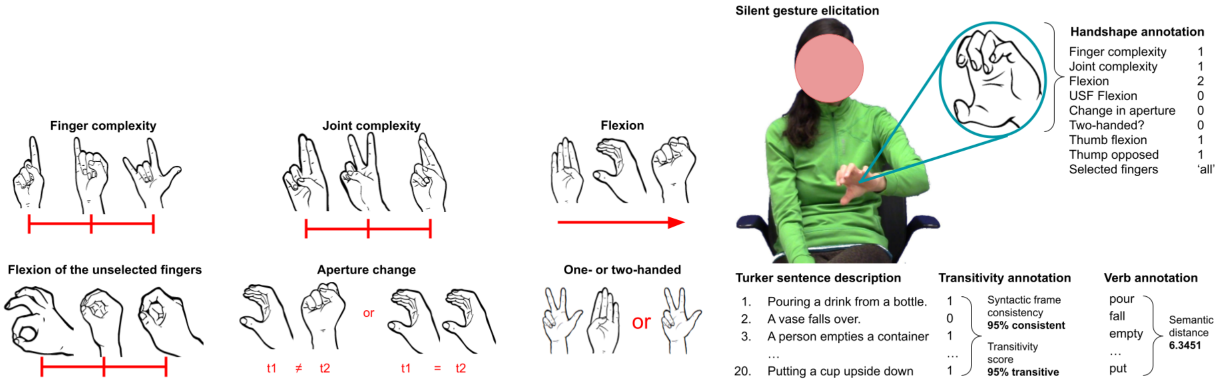
Top-down and bottom-up sources of meaning in silent gesture

Background: Research on sign language and silent gesture perception has indicated that non-signers consistently identify grammatical and semantic categories expressed in both mediums, like telicity and phi-features (Strickland et al., 2015; Schlenker, 2018), yet struggle with identifying their encyclopedic meaning (van Nispen et al., 2017; Sehyr & Emmorey, 2019). For instance, a non-signer might interpret the verb sign DECIDE as telic, but not know what it means. This has led some to stipulate that non-signers use perceptual cues to resolve meaning in a bottom-up way. However, others have argued that new signals (gestures, unfamiliar signs, artificial languages) are processed top-down, with the identification of subunits of meaning derived from first comprehending the overall meaning of the utterance (McNeill, 2005; Arbib, 2010; Lepic & Padden, 2017). We experimentally weigh these two positions using a silent-gesture perception study and follow up bottom-up (Analysis 1) and top-down (Analysis 2) analyses. We chose *transitivity* as the grammatical domain of interest given previous work demonstrating that this information is present in gesture production (e.g., Brentari et al., 2017).

Method: We elicited 276 gestures representing 46 unique events (23 transitive) from 6 non-signing participants, and annotated the gestures for 6 handshape features relevant to transitivity coding in sign languages (e.g., Brentari et al., *ibid.*; Fig. 1a). We performed a gesture labeling study on Amazon Mechanical Turk, wherein Turkers provided 1-2 sentences describing what they thought each gesture meant (20 sentences/gesture; Fig. 1b). **Anlys. 1:** Sentences were coded for transitivity such that each gesture was represented by a transitivity score, or the proportion of transitive sentences it received. To test whether handshape features predict how transitive a gesture was perceived (bottom-up hypothesis), we fit an OLS model to predict *Transitivity Score* from the 6 handshape features. **Anlys. 2:** For each sentence, we extracted the main verb(s) and computed the *Semantic Distance* between them. *Semantic Distance* was computed as the mean pair-wise Euclidean distance of the verbs' 300-dimensional vector representation (obtained from GLoVe; Pennington et al., 2014). To test whether the resolution of the meaning of a gesture modulates how consistently participants rated gestures as transitive or intransitive (top-down hypothesis), we first calculated *Consistency* as the normalized absolute distance from a maximally inconsistent baseline of 0.5 (i.e., if half of participants rated the gesture as transitive and the other half as intransitive). We then fit another OLS predicting *Consistency* from *Semantic Distance*.

Results: Anlys. 1: The bottom-up model was significantly predictive ($F(6,269) = 19.52$, $p < 0.001$) with moderate coverage ($R^2 = 0.3$). Three predictors significantly predicted the perceived transitivity of gestures: *Flexion* ($\beta = 0.14$), *Aperture change* ($\beta = -0.17$), and *Two-handed* ($\beta = 0.24$), all $p < 0.01$. **Anlys. 2:** The top-down model was also significantly predictive ($F(1,274) = 39.97$, $p < 0.001$), though its coverage was very low ($R^2 = 0.13$). The single predictor, *Semantic Distance*, was inversely related to consistency ($\beta = -0.04$; $p < 0.001$), indicating that closely related words were more likely to be consistently classed as in/transitive.

Interpretation: Both bottom-up and top-down models were significant, indicating that both information streams may be relevant to transitivity resolution. However, the bottom-up model explains more cases than the top-down model. For example, participants did not converge on a consistent interpretation for gestures depicting the event, *Someone crushed a soda can* (verbs included *mold, fight, smoosh*, and *interlace*), but they nearly all perceived the gestures as depicting a transitive event. We ground our interpretation of the bottom-up results in embodied theories of gesture/language comprehension, and suggest the constructs pre-evolved for recognizing manual actions (e.g., *grasping*; Rumiati et al., 2010) are co-opted for gesture comprehension.



(a) (b)

Figure 1: (a) **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). (b) **Experimental design, variable definitions:** A gesture depicting *Someone put a book on its side*, with Turker response sentences annotated for transitivity. For each gesture: *Transitivity Score* was calculated by averaging the number of transitive sentences the gesture received; *Consistency* was calculated as $|0.5 - t|/0.5$ where t is the *Transitivity Score*; *Semantic Distance* was calculated between each pair of verbs extracted from each sentence. Finally, handshape was annotated for features in (a).

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