What handshape tells us about active versus inactive articulators

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It is widely assumed in the articulatory phonology literature that when an articulator is not active (unspecified in the gestural score) it assumes a neutral state. One example of this is that the velum, when not active, assumes a closed position; only when it is actively opened does it deviate from that position. This assumption makes predictions about speech that seem to be fairly robust: nasal sounds are more marked than non-nasal, and nasalization spreads from nasal sounds, etc. This neutral position, however, is at odds with the position that the velum assumes naturally when people are at rest (eg not speaking), which is open allowing for air to be drawn into the respiratory system from the nose or mouth. This being the case, there must be some muscular activity on the velum during periods that have previously been described as inactivity in order to keep it closed. One solution to this apparent problem is to specify gestures for periods previously assumed to have no activity, although these gestures would necessarily be weaker than active articulator gestures.

There are two major predictions that come from the fact that the targets associated with nonactive gestures are not a physiologically neutral state, but rather a state that is default for speech. First, it is possible that the targets for nonactive gestures will differ cross linguistically with different languages having different default states. This is supported in work on spoken languages looking at default targets of nonactive articulators, or what are described as articulatory settings which vary from language to language (Wilson and Gick 2006; Wilson 2006; Gick et al. 2004). Second, it’s possible that the targets for nonactive gestures will vary depending on the targets of the active gestures. This will be used in the development of the articulatory phonology model of handshape proposed here for the configuration of the nonactive (nonselected) fingers.

Since the earliest theories of sign language phonology, handshapes have divided the fingers into selected and non-selected groups (Mandel 1981). The selected fingers are the likeliest sources of coarticulatory pressure. This talk presents an articulatory model of handshape (AMH) which explicitly links this distinction to the distinction of active and inactive articulators used widely in speech (Browman and Goldstein 1992). This link makes critical, testable predictions (eg hypothesis 1 below) about the nature of handshape variation due to coarticulatory pressure. The AMH is based on articulatory phonology (following Browman and Goldstein 1992) and can explain the phonetic implementation of handshape from phonological specifications. It explains variation due to articulatory effects (eg coarticulation) because it uses dynamic articulator gestures. That is, the articulators that make up the hand are not static, sequential configurations (ie discrete units), but rather individual articulator gestures overlapping across segments. This ability to model gradient phonetic implementation and contextual variation represents a critical improvement over previous phonological models.

1. The hand configurations of a letter vary predictably based on surrounding context, constrained by the following tendencies:
   (a) The nonselected fingers are targets of coarticulatory pressure.
   (b) The selected fingers are the likeliest sources of coarticulatory pressure.

Implementation — Unlike speech, the nonactive (nonselected) articulators (fingers) do not assume a single default position; they are either flexed or extended completely. Which configuration is chosen is generally predictable: the nonselected fingers are extended if the selected fingers are (more) flexed, and the nonselected fingers are flexed if the selected fingers are (more) extended (van der Hulst 1995; Brentari 1998). The AMH describes each handshape with a limited number of target categories (given in table 1). These specify the angles for the joints known to be contrastive in sign languages in two groups: the MCP and MP for the selected finger group and the MCP and IP for the secondary selected finger group. Nonselected fingers are associated with a binary specification for flexed or not. The phonetic realization of joint angles is continuous, although the phonology of any given sign language will divide that range into a small number (~ 3) of target categories. Testing the boundaries of these targets, especially crosslinguistically, is set aside for future work.

Testing predictions — An analysis of coarticulation of pinky extension revealed a puzzling fact: There is less pinky extension coarticulation in handshapes where the pinky is selected and flexed (~A, ~E, ~O, and ~S) compared to other handshapes where the pinky is nonselected and flexed (see figure 1 and 2). Despite having the same phonetic realization in both (flexed), the pinky behaves differently with respect to coarticulation depending on its membership in the selected fingers group. This follows directly from the AMH and the predictions above: in handshapes where the pinky is selected and flexed, there is less pinky extension as a result of coarticulation because the pinky is an active articulator, which suppresses coarticulatory pressure from surrounding articulator gestures because the flexion is associated with an (active) articulator gesture.

The AMH provides a concrete and principled way to convert the phonological specifications of handshape into phonetic configurations using a model of articulator targets and gestures developed for speech. Additionally, the AMH correctly predicts how the active or inactive status of particular articulators will affect variation in natural production.

²The AMH is broadly compatible with many phonological models of handshape (Sandler 1989; Brentari 1998; among others).

²In fact, the rest state is more open than even nasal segments (Bell-Berti 1993).
Table 1: Tract variables for all fingers — The articulatory model of handshape describes each handshape with a limited number of tract variables. The tract variable values are given as either binary features, or ranges of (joint)-angles. The phonetic realization of joint angles is continuous, although the phonology of any given sign language will divide that continuous range into targets of a small (circa 3) number of categories.

<table>
<thead>
<tr>
<th>group</th>
<th>joint 1</th>
<th>tract variable 1</th>
<th>values 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>selected fingers</td>
<td>MCP</td>
<td>SF-MCP</td>
<td>-15–90°</td>
</tr>
<tr>
<td></td>
<td>PIP</td>
<td>SF-PIP</td>
<td>0–90°</td>
</tr>
<tr>
<td></td>
<td>MCP</td>
<td>SF-ABDUCTION</td>
<td>[± ABDUCTED]</td>
</tr>
<tr>
<td>secondary selected fingers</td>
<td>MCP</td>
<td>SFS-MCP</td>
<td>-15–90°</td>
</tr>
<tr>
<td></td>
<td>PIP</td>
<td>SFS-PIP</td>
<td>0–90°</td>
</tr>
<tr>
<td>thumb opposition</td>
<td>CM</td>
<td>CM</td>
<td>-45–90°</td>
</tr>
<tr>
<td>nonselected fingers</td>
<td>all</td>
<td>nsf</td>
<td>[± FLEXED]</td>
</tr>
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</table>

Figure 1: A plot showing the effect of conditioning apogees (-ə-, -ɪ-, and -ʏ-) on the probability of pinky extension at mean transition times for both previous and following. Dots are model predictions for an apogee with a conditioning apogee in the previous position, following position, both, or neither. The lines are 2 standard deviations on either side. The order of the 8-letters is based on the overall amount of pinky extension. Note that the model shows low probability of pinky extension for letters (-ɑ-, -ɛ-, -ơ-, and -ʊ-) even when there are conditions letters on either or both sides.

Figure 2: (a) canonical -l-, (b) -l- with pinky extension; -ɑ- and -s- (c and d respectively) have nearly no pinky extension even though the pinky is flexed similar as in the -l- handshape, it is active, and thus not susceptible to pinky extension coarticulatory pressure.