LIP ROUNDING AS SIDE CONTACT

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ABSTRACT

Data are examined to determine the "goal" of the articulatory gesture(s) for lip rounding. It is hypothesized that rounded vowels differ from unrounded vowels in the presence vs. absence of contact between the upper and lower lips along their sides.

1. ARTICULATORY PHONOLOGY

In the articulatory phonology approach developed in the last few years [2,3,4], phonological units are *gestures*. Each is modeled as a dynamical regime that controls the formation of a constriction within one of the relatively independent vocal tract subsystems (i.e., the lips, tongue tip/blade, tongue body, glottis, and velum). The constriction goals for a given gesture are defined, not at the level of individual articulators, but at a *task* level [10,11], where the task specifies the degree (and for oral articulators the location) of the vocal tract constriction. For example, the goal of the bilabial closure gesture at the beginning of the word "bad" is defined in terms of the task or *tract variable* of *lip aperture*, the vertical distance between the upper and lower lips.

One consequence of this approach is that phonological units can be defined relatively invariantly in terms of tract variables. Contextual variation in the relative contributions of individual articulators to a given gesture emerges automatically as a consequence of the temporal overlap among invariantly specified gestures, because an individual articulator's motion is determined by the entire ensemble of concurrently active gestures to which it is relevant. Thus, in the case of the bilabial closure gesture, the relative contribution of the upper lip, lower lip and jaw to lip aperture will automatically differ depending on the jaw requirements of an overlapping (co-produced) vowel gesture [4, 11].

2. LIP GESTURES

Lip constrictions can be described in three dimensions:

LA, Lip Aperture: Vertical distance between the upper and lower lips measured at the center of the lips when viewed from the front.

LW, Lip Width: Side to side measure of lip opening when viewed from the front.

LP, Lip Protrusion: Protrusion of the upper or lower lips from the teeth, as seen in profile. More generally, this this is taken to be anterior-superior positioning of the lips with respect to the teeth, encompassing both "protrusion" and "retraction".

The object of this paper is to investigate which of these dimensions are specified in the "task" control of various lip gestures.

2.1 Consonant Constrictions

As noted above, lip closure gestures can be specified using LA [2,4,10,11]. It is unlikely that any additional specification of LP or LW is required. However, LP is clearly important for labiodental fricatives, in which there is retraction (of the lower lip).

2.2 Rounding and Vowels

While it is possible to hypothesize a relatively invariant tract variable goal for lip closure gestures (in terms of LA), it is more difficult to do so in the case of lip rounding gestures. All three constriction dimensions have been investigated [1,6,9] as potentially relevant to distinguishing vowels on the basis of lip rounding. However, each has been shown to vary considerably from vowel to vowel, for both rounded and unrounded vowels.

The hypothesis proposed here is that none of these constriction dimensions is used to specify the "task" goals for gestures that distinguish rounded from unrounded vowels. Rather, what is specified is whether or not the *upper and lower lips touch along their sides*. Specifically:

(1) Phonologically "rounded" vowels must be produced with contact along the sides (upper and lower lips touching).

(2) Phonologically "unrounded" vowels must be produced with *no* contact along the sides.

If side contact is what is specified for vowel gestures (positively for "rounded" vowels, negatively for "unrounded" vowels), then direct measurement of the length of contact along the sides of the lips should categorically divide the set of rounded vowels from the set of unrounded vowels. Distance from the corner of the mouth to the most forward point of contact was measured in Linker's [9] cross-language study of rounding, and her data for Cantonese, Finnish, French, and Swedish are plotted here in Fig. 1. In general, all the vowels that are phonologically rounded have substantial side contact, while unrounded vowels have virtually none. If .9 millimeters is set as an absolute (speaker- and language-independent) criterion for contact, then all but three of the 272 vowel tokens from eight speakers of four languages are appropriately classified. Note that for Swedish, this means that both the "inrounded" as well as the "outrounded" vowels (as traditionally described [5]) are classified as rounded. (Note that the symbol /ɯ/ is used here for the high front "inrounded" vowel). Differences between the two types of rounding will be discussed below. Also, Swedish /ɑː/ is here classed with the rounded vowels. There are differences in the literature as to the status of rounding in this vowel [5,7] (and in any case, rounding is not contrastive for low vowels in Swedish).

Given this side contact specification, the patterns of variation shown by LA and LW both within and across rounding classes are predictable, as will be argued below. In addition, it is possible for LP to be specified independently of the *touching/no touching* specification. In such cases (e.g., Swedish, below), LP may contrast within the class of rounded vowels as defined by (1). In other cases, LP may contribute, as an "articulator," to side contact (or its absence), with the exact amount of LP determined in a language-specific or speaker-specific fashion.

Finally, in this analysis, rounding and consonant constrictions can be seen as complementary. Consonants control the vertical opening between the two lips along the midline, while rounding for vowels controls the opening along the sides (Rounding for consonants has not been analyzed from this perspective).

3. UNROUNDED VOWELS

For unrounded vowels, LA has been observed to vary considerably without any concomittant variation in LW. This can be seen in the English data presented by Fromkin [6]. This independence of LW and LA follows from the hypothesis that the sides of the lips do not touch in such vowels. As illustrated in the frontal views in Fig. 2, if the sides don't touch, LA can change substantially without automatically changing LW.

The differences in LA among the unrounded vowels probably do not have to be specified as part of the task-dynamic control for these vowels. As Fromkin notes, LA variations are predictable from the different jaw heights found for the vowels. In fact, the slope of the relation between LA and jaw height appears to be about one in her data. Thus, millimeter for millimeter, all of the variation in LA can be attributed to the jaw positioning. In the task dynamic model, these different jaw heights result, in turn, from the different requirements of tongue positioning. Thus, no active control of LA would be required.

Spreading. The vowel /i/ has been shown to involve active retraction of the corners of the lips in English [12] and in

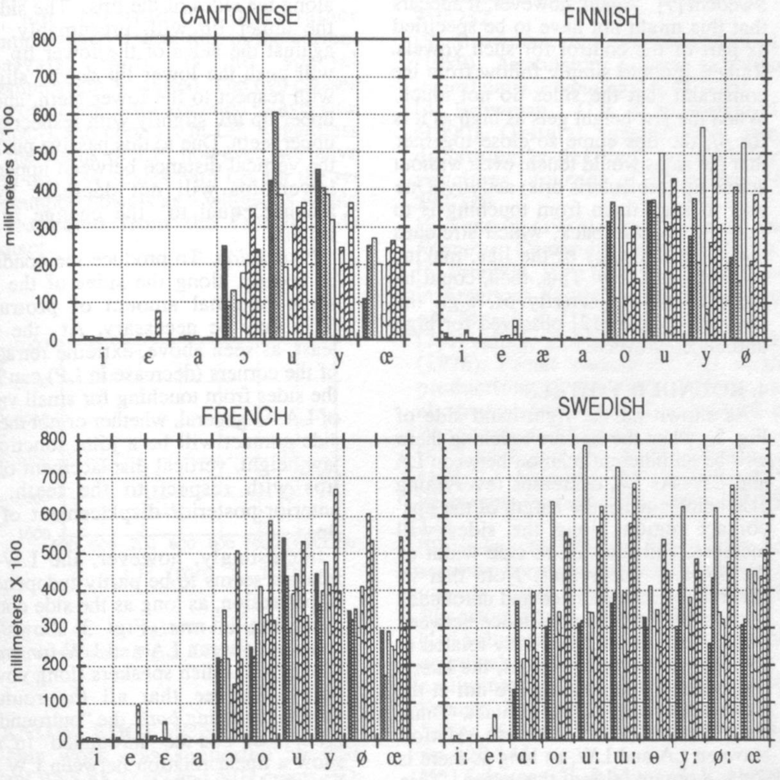

Figure 1. Length of contact along sides of lips. For each vowel, separate bars represent single tokens from each of eight speakers. (All Cantonese and Finnish vowels are long). Data from Linker [9].

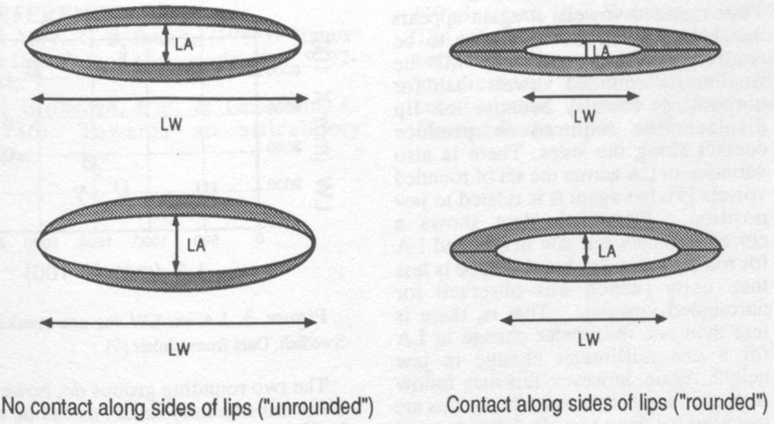

Figure 2. Hypothesized effects of changing LA as a function of side contact.

Swedish [7]. Again, however, it appears that this might not have to be specified as part of the control for such vowels. Rather, it could simply follow from the constraint that the sides do not touch. When the jaw height gets as high as it is for /i/, the lips come so close together that the sides would touch, even without active lip (orbicularis oris) activity. One way to keep them from touching is to pull the corners back, which stretches and thins the sides of the lips, making contact less likely. This, then, could be the goal of the activity of, e.g., the *risorius* muscle [12] observed for high unrounded vowels.

4. ROUNDED VOWELS

As shown on the right-hand side of Fig. 2, when the lips are touching there will be an inherent relation between LA and LW. As LA decreases (everything else being equal), the length of the lips' contact region along the sides will increase, and the side-to-side width of the *opening* decreases. Note that in general, for both rounded and unrounded vowels, the horizontal distance between the *corners* is not inherently related to LA. But for rounded vowels, the lateral endpoints of the opening are not at the corners, because of the contact. Thus, there should be an inherent relation between LA and LW, as long as there is some contact along the sides. This relation can be seen for the rounded vowels in English [5], and possibly in French, Abry and Boe [1].

For rounded vowels, it again appears that LA, per se, does not have to be controlled. In general, LA will be smaller for rounded vowels than for unrounded vowels, because of lip displacement required to produce contact along the sides. There is also variation in LA across the set of rounded vowels [5], but again it is related to jaw position. Fromkin's data shows a correlation between jaw height and LA for rounded vowels, but the slope is less than unity (which was observed for unrounded vowels). That is, there is less than one millimeter change in LA for a one millimeter change in jaw height. Again, however, this may follow from the fact that the sides of the lips are touching for these vowels. Imagine what happens as the jaw raises in a configuration in which there is contact along the sides of the lips. The sides of the upper lip will, presumably, push against the sides of the lower lip. This will push the lower lip *down* slightly with respect to the lower teeth, and the upper lip *up* slightly with respect to the upper teeth. Due to this passive pushing, the vertical distance between upper and lower lips will not decrease by an amount equal to the change in jaw height.

Protrusion. To produce the condition of contact along the sides of the lips, some minimal amount of protrusion (LP) may be necessary. At the very least, as seen above, extreme retraction of the corners (decrease in LP) can keep the sides from touching for small values of LA. In general, whether or not there is side contact will be a joint function of jaw height, vertical displacement of the lips with respect to the teeth, and anterior-posterior displacement of the lips.

Interestingly, however, the LW-LA relation seems to be partly independent of protrusion, as long as the side contact condition is met. Fig. 3 shows the relation between LA and LW for one of Linker's Swedish speakers (long vowels only). We see that all the rounded vowels including *both* the "outrounded" (y, ø, o, ɑ) and the "inrounded" (u, ɯ), show a linear relation between LW and LA. As long as the sides are touching, these variables scale with each other, regardless of the amount of LP.

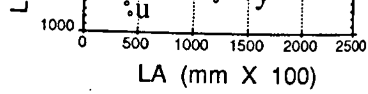

Figure 3. LA vs. LW for one speaker of Swedish. Data from Linker [9].

The two rounding groups *do,* however, differ substantially in LP, as can be seen in Figure 4. This is consistent with Ladefoged and Maddieson's [8] characterization of "outrounded" vowels as [protruded], and "inrounded" vowels as not [protruded] (but rather [compressed]). Note that in the current analysis, there is no special "compression" required. The two classes of vowel are both rounded (have side contact), but contrast in LP. Regardless of the status of LP, however, we have seen that LW scales with LA for the set of rounded vowels as a whole, as would be expected from the fact of side contact.

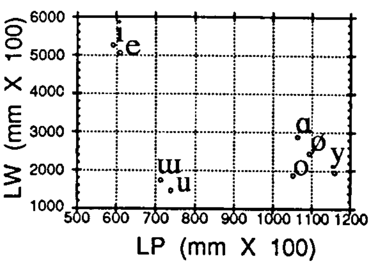

Figure 4. LP vs. LW for the speaker of Swedish, shown in Fig. 3. Data from Linker [9].

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