Exploring children's developing A-maps: accuracy, precision, and the noise function

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The A(rticulatory)-map was recently proposed to account for developmental and acquired phonological production patterns (McAllister Byun et al. in press). This model incorporates intuitions expressed in the current literature on language acquisition (Curtin & Werker 2007; Pierrehumbert 2003; Werker & Curtin 2005) within the formal apparatus of Harmonic Grammar (Legendre et al. 1990; Pater 2009; Smolensky & Legendre 2006). It provides a mechanism to capture motor-grammar interactions within the speaker's phonological grammar, where motor pressures make reference to the notion of efference copies, the predicted sensory outcomes of given motor plans (Wolpert et al. 2001). These are represented as *E* in (1), which formally encodes the need to match phonological targets. ACCURATE interacts with PRECISE in (2), which encodes the pressure to realize given target using a motor plan that can be executed reliably.

(1) ACCURATE: For a candidate $c_{[i,j]}$ with associated motor plan $MP_{[j]}$ that maps to a predicted acoustic-perceptual outcome $E_{mean[j]}$, assign a penalty in proportion to the distance in acoustic-perceptual space between $E_{mean[j]}$ and the target $T_{mean[i]}$.

(2) PRECISE: For a candidate $c_{[i,j]}$ with associated motor plan $MP_{[j]}$, assign a penalty in proportion to the magnitude of Noise($MP_{[j]}$).

As stated in (2), PRECISE computes grammatical outcomes through a noise (variability) function:

(3) Noise($MP_{[i]}$): The average distance between pairs of episodic traces (*E*, *T*) generated in connection with previous executions of a given motor plan, $MP_{[i]}$.

Noise measures the distance between past expectations and outcomes of a given motor plan. This function successfully to capture patterns of fricative stopping in child phonology: the grammar selects a precise (low-noise) pattern at the expense of accuracy (McAllister Byun et al. in press).

While fricative stopping data often contrast fairly distinct behaviours (stop vs. continuant outcomes), the effectiveness of the A-map remains to be explored across additional phonological contexts. In this paper, I explore the interaction between ACCURATE and PRECISE, with a focus on the Noise function, through looking at two additional contexts. The first concerns the development of phonological units that are more variable. Taking liquid consonants as a prototypical example of such contexts, I begin with a comparison of English, German, and French data available through the PhonBank database (http://childes.talkbank.org/phon), I show that English liquids typically show more variability than German and French ones, which reflect the phonetic properties of both target systems: English liquids are phonetically more variable (in both perception and production) than those of German or French. This variability has direct implications for the noise function, which accounts for the more gradual learning curve observed in English, as evidenced by a comparison between Fig. 1 (English) versus Fig. 2 (German) below.

The second context involves general patterns of segmental deletion, often typical of early stages of phonological development, especially in second positions of complex onsets or in syllable codas (Barlow 1997; Fikkert 1994; Rose 2000). I argue that in these contexts the child has not yet established a motor plan (MP) to reproduce this target. This translates into an overwhelmingly high index in the noise function, which undermines the selection of all output candidates. Deletion occurs as a result, as the only accurate-enough grammatical outcome.

While general tendencies in development may be understood in terms of the overall phonological and phonetic properties of target languages, variability between children learning a given language can be captured via their individualized A-maps, which are influenced by individual differences in maturation and production experience. Looking more closely at emerging production patterns, the data also suggest that the A-map gradually comes to operate over increasingly small units of representation, which can be tied to their emerging degree of phonological abstraction across different phonological positions (Munson et al. 2011).

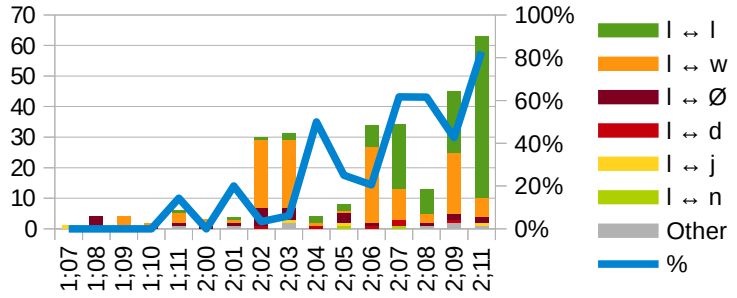

Figure 1: /l/ in singleton onsets - English data (Charlotte)

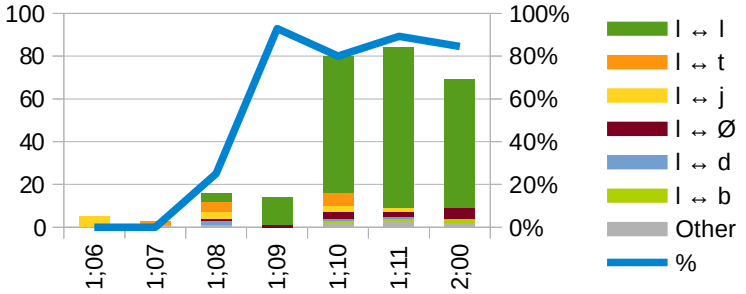

Figure 2: /l/ in singleton onsets - German data (Nele)

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