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Two-year-old Dutch- and Russian-speaking children: Exploring the vowel space

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The developmental process from young infants’ vocalizations towards the more adult-like vowels in speech of older children is not yet unraveled. We assume that even two-year-old children are still exploring the possibilities of their speech apparatus, perceptually as well as in a sensori-motor sense. There is also a clear need for investigating vowel development in children from various languages. Vowel systems vary along several articulatory dimensions (e.g., jaw- and tongue position, lip rounding, duration of vowels). These differences have acoustic correlates (e.g., the dimensions of the $F_1$-$F_2$-plane).

In the present study, we compare the vowel spaces of 5 Dutch- and 5 Russian speaking two-year-old boys. The children were audio recorded longitudinally in naturalistic home settings. Per child 50 unlabeled utterances at two years of age are selected that meet sensori-motor criteria (presence of phonation, eventually plus articulation).

Part of the acoustic problem in vowel acquisition research is the high pitch in children’s speech. Usually, researchers first label vocalic segments perceptually. Formant values are then determined with the knowledge about the perceptual quality of segments (e.g., perceived speech sounds) in mind. One major advantage of using an automated spectro-temporal analysis over the hand-edited formant measurement method is that the first method results in reliable, un-biased measurement values.

We have developed a more objective method for analysing children’s sound productions that does not require the labeling of vowel-like segments. Maximally 10 measurement points per utterance are selected automatically, thus accounting for articulatory drifting. Per voiced segment a bandfilter analysis is done. Instead of formant estimation, a whole spectrum approach (0 – 7 kHz) of the filter output is chosen. Data reduction of all 40 filter outputs is achieved via Principal Component Analysis (PCA). Previous research suggests that the first two principal components are strongly related to the $F_1$ and $F_2$ values of vowels.

A common reference plane for Dutch and Russian is constructed by using the first two eigenvectors of the PCA. However, this ‘vowel space’ comes from unlabeled data. For interpretation, we projected the results from our automated analysis applied to three labeled corner vowel realisations of the children into that plane. The vowel realisations were judged perceptually to be correct for Dutch and Russian by the two authors.

Results indicate for example that two-year-old Dutch children produce an /i/-vowel already nicely located and distinct from /u/ and /a/ locations. The large spread in their /a/ and /a/ corner vowel productions can possibly be explained by a still existing articulatory instability in two-year-olds.

The data processing of unlabeled vocalisations can be done quickly and consistently. Via this approach, important similarities and differences in vowel acquisition patterns with age, and in various languages can be uncovered, as well as dynamic behaviour, thus identifying elements of a theory of vowel acquisition.

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