Audio-tactile aids for teaching articulatory phonetics to EFL students with visual impairment

Research suggests that visual articulatory aids could be effective in helping learners acquire L2 speech sounds (Li 2016). Articulatory information in English pronunciation textbooks (Cruttenden 2014) and software (*icSpeech*) however is inaccessible to people with visual impairments (PVI). We present three tactile aids for teaching EFL articulation to advanced learners with varying degrees of VI. The first two devices display a model of the vocal tract and provide an audio-haptic interface that helps the student to learn the parts of the vocal tract. The third device is a refreshable display of electropalatographic (EPG) data for consonants and of midsagittal electromagnetic articulography (EMA) data for vowels, with functionalities that enable highlighting contrasts between Polish and English articulation.

The first device is a 20×20x5cm box with the top lid in the form of an interactive relief model of the vocal tract in rest position 3D-printed in 2.5D. The details of the vocal tract are marked by raised lines and textures on a flat background. The details have been grouped in 12 sections (lips, nasal cavity, tongue tip, etc.), each has been coated with electrically conductive paint so that it plays the audio name of the section when touched by the user. The properties of lines and textures follow accessibility guidelines (Wabiński et al. 2022: 12). The device operates in a training and testing mode. During the latter, it asks the user to name random sections indicated by vibration motors placed below, it listens to the following utterance, recognizes it, evaluates and plays audio feedback. Similar systems were implemented for maps (Brulé et al. 2016) as well as teaching IPA (Gonzalez - Yeimy 2020), biology (Kolitsky 2014) and arts (Cavazos Quero et al. 2021).

The second device is a model of the vocal tract identical to the 2.5D model except it is not 3D-printed by the authors but based on a commercially available anatomically correct scale 3D model of the vocal tract, and that it only operates in the training mode.

The third device is a refreshable articulation display contained in a 12×20x8cm box. It activates pins protruding vertically through the top lid of that box to display tongue-to-palate contacts for consonants and midsaggital tongue contours for vowels. Tongue-to-palate contacts have been modelled on EPG data from a Polish and an English native speaker using *Linguagraph* system. To display the EPG pattern, 31 pins arranged as in the left half of the Reading-type palate electrode layout are moved between two states (0, 3mm) by linear solenoid actuators. Tongue contours for vowels have been modelled based on EMA data from a Polish and an English native speaker using *Carstens* AG500. To display EMA patterns, miniature stepper motors adjust the height (0-10mm) of 8 pins arranged in a line parallel to and 5mm off the left border of a 3D-printed negative shape of the right half of the palate 3D-scanned from one of the speakers and flattened by 30%. The consonant display is roughly symmetric to the flattened palate with the vowel display 15mm to the right of the axis of symmetry. The voice commands enable the display of all Polish consonants and vowels that have their counterparts in English, phonemes that are unique to each language, as well as retrieving articulation of a phoneme by its articulatory description.

The prototypes underwent an iteration that applied improvements based on the feedback from an adult Polish learner of English with VI. Future research will focus on adding reliefs with other articulator positions to the 2.5D device, incorporating all devices into an EFL curriculum and testing them in a group of students with VI.

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