Additional Physical Models of the Human Vocal Tract as Tools for Education in Language Learning

Eri Maeda and Takayuki Arai

Department of Electrical and Electronics Engineering
Sophia University, Tokyo, Japan
m-eri@sophia.ac.jp

Abstract

We have proposed several mechanical models of the human vocal tract for the Japanese vowels /i/, /e/, /a/, /o/, and /u/ with a view toward education in acoustics. We used the models during a lecture in a university-level speech science class as well as in a high school physics class, and confirmed their effectiveness as educational tools.

Earlier, we added a new feature to the models. In a previous study, we investigated nasalized vowels, and for this purpose, we designed and reported on a nasal cavity attachment for one of the models. We then examined the effect of velopharyngeal coupling.

Educational tools for acoustics and linguistics have gradually become more accessible in recent years, for example: computer simulation, E-learning, and website study. Although it might be worthwhile to integrate the physical models with computer simulation for advanced students, we feel the physical models are better suited for introductory instruction.

In the present study, we propose several new models for language learning. One new type of model is designed to teach the /r/-/l/ distinction. Many Japanese speakers have problems producing and perceiving the difference between /r/ and /l/. We have made physical models that produce /r/ and /l/ to address this problem. We believe the models will be especially useful for second language acquisition.

1. Introduction

We recently replicated Chiba and Kajiyama's physical models of the human vocal tract [1]. We found that they are effective tools for education in acoustics, not only for scientific research [2]. In a previous study, we reviewed the history of education in acoustics, made observations on how education in acoustics needs to be, and then discussed the usefulness of the physical models of the human vocal tract for education in light of our observations [3].

We then suggested that our educational models are useful for teaching acoustics not only to engineering students but also humanity students who do not have a technical background. Also, we showed the usefulness of the vocal tract models for teaching different levels of students, from elementary school to college level [4]. As an example, we reported their effectiveness with high-school students who had just finished studying basic acoustics [2]. We concluded that using physical models of the human vocal tract clearly enhances education in Acoustics.

2. Our models

Using Chiba and Kajiyama's measurements [1], Arai reconstructed their vocal tract models to make models suitable for education [5]. Arai proposed two types of models: the plate type model, which is a step-wise approximation of Chiba and Kajiyama's original measurements [1], and the cylinder-type model, with a precise reproduction of the original measurements. The models have an opening at each end corresponding to the mouth and glottis, and they are made of transparent acrylic resin so the shape of the cavity can be seen.

We also proposed models for nasalized vowels. These models were designed to simulate the hypernasality of cleft palate patients [6,7]. The nasal models have a nasal cavity and sinuses. One of the models is shown in Fig. 1. We disscused the effect of the sinuses and velopharyngeal opening on nasalization of the produced sounds.

In addition to these models, Arai et al. [9] noted the importance of Umeda and Teranishi's vocal tract model [8]. Their model has oral and nasal cavities coupled by a connecting rotating valve, which simulates velopharyngeal function. The cross-sectional areas of this model may be changed by moving plastic strips that are inserted from one side. This is an important tool for Acoustics education. In particular, this model allows students to see how a narrow constriction affects sound quality. For example, students can observe that making a narrow constriction at the retroflex position produces a rhotacized vowel.

3. New models

In this demonstration, we show several new types of models as well as the previous models we have developed. The new models are specially designed to teach the /r/-/l/ distinction in English.

It is well known that phonetic contrasts in one language may be difficult for speakers of another language to perceive and/or produce. For example, the English /r/-/l/ contrast is remarkably difficult for

Japanese speakers to perceive and produce even after many years of education in English or immersion in an English-speaking environment [10,11]. Yamada et al. [10] demonstrated that training in the perceptual domain produces long-term modifications in both perception and production.

To address this problem, two types of models were proposed which are intended to train students in the perceptual domain (i.e. distinguishing between /r/ and /l/). The first type is based on figures appearing in Stevens [12]. They are made of transparent (exterior) and black (interior) acrylic plates, so that the internal shape of the oral cavity can be seen, as shown in Fig. 2 (a) for /r/ and (b) for /l/. The other type of model is the 'kinetic sculpture' model which is manually operated to change the oral cavity as shown in Fig. 2 (c). The inspiration for this model is the wooden midsagittal head models used for Acoustics education [2]. It is hoped that by using these models, students will be better able to distinguish between /l/ and /r/.

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Figure 1: Model of the human vocal tract for nasalised vowel /a/.

(a) (b)

(c)

Figure 2: New physical models of the human vocal tract.