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Effects of constitutive and dynamic properties of the vibrating vocal folds on vocal frequency perturbations

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Introduction

The object of the presentation is the modelling of vocal jitter and flutter in type I voices, which are voices that are monophonic and pseudo-periodic. A formal model of the cause of vocal jitter and flutter has been proposed by Titze [1]. It involves a simulation of the fluctuations of the tension of the TA-muscle (a.k.a. the "body" of the vocal fold) owing to the spatial and temporal superposition of muscle twitches.

We would like to argue that the fluctuations of the tension of the TA-muscle may cause observed vocal frequency perturbations, but that the latter are not a copy of the former. Titze's model may explain, as a consequence, a wider range of phenomena and dispense with the need to postulate the appearance of novel causes of perturbations each time increased jitter or mild hoarseness are observed in type I voices.

The impetus for the investigation is the common experience that vocal loading together with dehydration, smoking, (pre-)menstruation in women or light laryngitis may increase vocal jitter and cause mild hoarseness in type I voices. Fourcin has proposed a physiological model of the former, which involves injecting atropine in the folds [2]. The observation that atropine injection increases vocal jitter whereas, as a rule, moderate vocal loading decreases jitter, suggests that constitutive or dynamic properties of the folds may alter observed perturbations. Fourcin has indeed assigned the boost of jitter to an increase of the damping of the cover.

Method

We consider the predictions of three existing models and report two simulation experiments.

(A) A first model kinematically simulates the vibration of the edge of a vocal fold by the sum of a constant abduction and two sinusoids (body and cover). The phase of the sinusoid mimicking the vibration of the fold body is perturbed feebly. (B) The second model involves the derivative of a formula in [3] that relates the active and passive tension of the vocal fold to its natural frequency of vibration.

(C) The third model is a lumped three mass model of the vocal folds [4], which involves 9 control parameters the values of which are randomly chosen in physiologically plausible intervals. All signals have been type I exclusively. The purpose of a *first* set of 1000 *perturbation-free* simulations of sustained [a] sounds has been to *interpret* via model (C) the predictions of models (A) and (B). The purpose of a *second* set of 1000 simulations has been to *reproduce* via model (C) the predictions of models (A) and (B) by perturbing randomly the stiffness of the body and recording the perturbations of the frequency of vibration of the body and cover.

Results and discussion

(i) Models (A) and (B) predict that observed frequency perturbations evolve proportionally to the relative amplitude $a_b/(a_b+a_c)$. That is, observed perturbations increase when the body and cover amplitudes of vibration a_b and a_c respectively increase and decrease. In addition, model (B) predicts that observed perturbations decrease with the natural frequency of vibration of the folds.

(ii) Regression analysis of the *first* set of simulations shows that the relative amplitude $a_b/(a_b+a_c)$ evolves proportionally to the relative vibrating mass $m_c/(m_b+m_c)$, which is the most influential control parameter by far.

(iii) Regression analysis of the *second* set of simulations confirms the pre-eminence of the relative vibrating mass. The second-most important parameter that boosts observed frequency perturbations is pulmonary pressure. The regression weights of the remaining parameters are small and they (damping included) attenuate perturbations. The damping of the cover has a major influence on the open quotient and average glottal area, however.

In the framework of model [4], increased damping of the cover therefore favours "breathiness" via the increase of the open quotient, whereas excess secretions on or swelling of the cover favour "roughness". Increased damping may boost "roughness" indirectly provided that the speaker compensates increased "breathiness" by increased pulmonary pressure.

References

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