# Perturbation of Voice Signals in Register Transitions on Sustained Frequency in Professional Tenors

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**Summary: Purpose.** Vocal register transitions in the passaggio region remain an unclarified field in classically trained male singers.

**Method.** We examined the acoustic and electroglottographic signals of seven tenors' transitions from voix mixte to falsetto on a sustained pitch F4 (349 Hz) on the vowels /a, e, i, o, u, and æ/.

**Results.** It was found that in many of the tested subjects, register transitions between voix mixte and falsetto were performed very continuously without clear register transition events. However, an increase of frequency and amplitude perturbation (jitter, relative average perturbation, and shimmer) was observed during register transitions.

**Conclusion.** These data suggest that professional tenors are able to avoid sudden registration events frequently observed in untrained voices.

**Key Words:** Register–Modal–Transition–Falsetto–Voix mixte–Jitter–Shimmer.

## INTRODUCTION

Vocal registers can be defined and characterized based on mechanical principles and/or sound characteristics.[1–7] Both kinds of register definitions are based on the assumption that register-associated vocal properties can only be continued over a definite voice range and can be separated from each other by means of differences between the mechanical principle and/or the sound characteristics, respectively. Vocal registers can overlap in their fundamental frequency (F0) range.[8] In this overlapping range, voluntary or involuntary register transition events might occur.[9–11] For tenors in particular, singing in and above the region where register events between modal register and falsetto usually occur (passaggio) belongs to the most difficult tasks of voice training. In contrast to unmodulated falsetto, this register function for professional singing above passaggio has previously been denoted as voix mixte, Volltonstimme, Vollstimme der Bruststimme, or full head.[10,12–15] In the present study, the term voix mixte is chosen, although this term is sometimes used with slightly different definition.[16]

On the voice source level, it was shown that for ascending register transitions from modal to falsetto register perturbation values, such as jitter, relative average perturbation (RAP), and shimmer, were increased for both untrained male voices and professional tenors.[15,17] However, while performing descending transitions, there was a lack of such an increase for frequency perturbation in the professional singer subjects.[15] Interestingly, comparable increases of frequency perturbation measures were found for transitions from modal to voix mixte function in professional tenors.[15]

The increase of perturbation during ascending frequency glides on the one side, and the lack of perturbation during descending frequency glides on the other, lead to the question; what happens if register transitions are performed on the same F0? In contrast to untrained voices professional voices are mostly able to perform register transitions on sustained F0. Since jitter—in contrast to RAP—could be affected by long-term frequency changes,[17] it seems additionally of interest to assess whether perturbation values are increased independent from frequency changes in register transitions.

In 1972, Large et al[10] were analyzing register transitions from full head (the term full head is used quite similarly to the term voix mixte in the present study) to falsetto on sustained pitches. In their study on two tenor, two baritone, and one bass subject, they were able to document differences of the overtone spectrum and flow. However, the examined subjects produced their changes on different F0s and those subjects were not asked to blend acoustic differences between the registers, thus, resulting in what the authors denoted as "breaks." Register differences were also observed by studying electroglottographic (EGG) voice signals in register transitions in glissandi and sustained pitches in trained and untrained voices by Roubeau et al[18] and Henrich et al,[19] respectively. The authors observed changes of EGG open quotient and amplitude. However, also in these studies, the subjects were not explicitly advised to smooth or blend register transition as much

**TABLE 1.**
**Subjects, Age, Profession, and Taxonomy According to the Bunch and Chapman[29] Criteria**

| Subject | Age | Profession | Taxonomy |
|---|---|---|---|
| 1 | 34 | Professional choir | 2.15 |
| 2 | 45 | Soloist, freelancer | 3.17 |
| 3 | 24 | Soloist, opera house | 3.1a |
| 4 | 30 | Soloist, opera house | 3.1a |
| 5 | 33 | Soloist, opera house | 3.1a |
| 6 | 36 | Soloist, opera house | 4.1a |
| 7 | 30 | Soloist, opera house | 4.1a |

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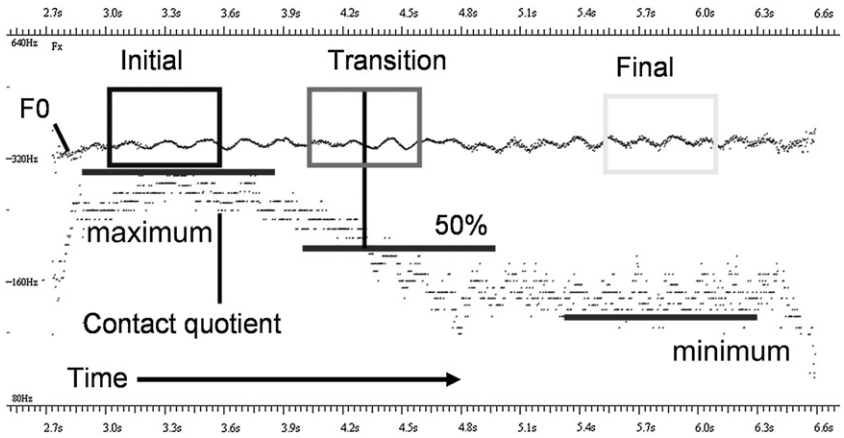


**FIGURE 1.** F0 and contact quotient data plotted against time. The construction of initial part, transition part, and final part window are shown. F0, fundamental frequency.

as possible. In 1982, Kitzing[20] was analyzing register transitions in untrained subjects and a single tenor subject. Here, the tenor subject was asked to perform register transitions on musical scales and equalize register differences. However, he was only able to do so for his transition to what the author denoted as operatic head register but not for falsetto register.[20] In fact, blending of such acoustic differences is of great interest in register research. It is assumed that the lowering of intensity with an increase of open quotient before the register shift between modal register and falsetto could provide a solution for blending.[19] Because for male western classical singing mostly tenors have to phonate in the passaggio region, it seems of interest if professional tenors are able to blend differences associated with registers, such as voix mixte and falsetto, respectively.

The present study was performed to analyze register transitions from voix mixte to falsetto on sustained F0 inside the passaggio region. It was hypothesized that in professional tenors perturbation values are increased during register transitions and none of the subjects were able to blend register borders absolutely by means of total continuous changes of voice signals, both audio and EGG signals.

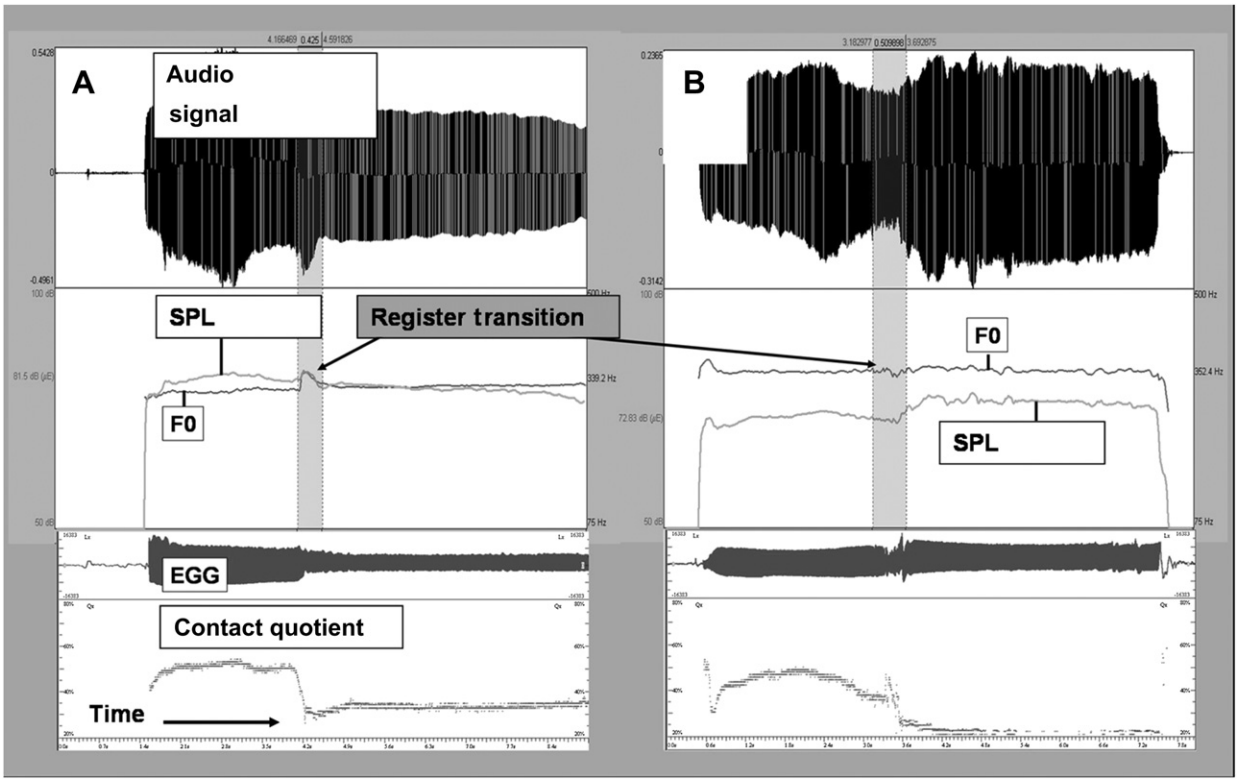


**FIGURE 2.** Two examples (**A** and **B**, respectively) of transitions from voix mixte to falsetto with clear register transition event. F0, fundamental frequency; SPL, sound pressure level; EGG, electroglottogram.