STUDY OF VOCAL PITCH VIBRATO PERCEPTION USING SYNTHESIS

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1.INTRODUCTION

The vibrato is one of the main musical ornaments in classical occidental music, particularly in the art of singing. Many researchers have studied and measured the main vocal pitch vibrato characteristics: average extent and rate of pulsation. Our study concerns short duration tones with vibrato, during pitch transitions or very short *staccato* notes. After analysing the performance of several great singers, some examples were synthesized to test our perceptive hypotheses.

2.EXPERIMENTAL METHOD

synthesis

Formant-Wave-Form synthesis was implemented on a micro-computer using a DSP board with a 16bit D/A converter, at a 16 kHz sampling rate. This method simulates a parallel formant synthesizer [Rodet 80]. An interfacing program allows easy manipulation of vibrato parameters (rate of pulsation, extent, duration), and musical note parameters (fundamental frequency, duration, loudness).

listening tests

The fifteen subjects were all musicians (two of them were singers). Two presentation conditions were used, the first with headphones and the second with loudspeakers, without differences concerning the results. During the presentation of the first series of short duration examples, about half of the subjects attributed the perceived differences to timbre variations. They were asked to focus on pitch variation. The influence of this kind of pitch variation on timbre will be investigated in future studies.

notation

The following terminology is introduced in Fig. 1: Δf is the extent of vibrato, $R = \frac{1}{T}$ the rate of pulsation, f_0 the fundamental frequency. For these examples, $\Delta f = 4.5\%$ of f_0 (80 Cents or 20 Savarts), and $T = 0.16s$, $R = 6.25Hz$. Parts 1-3 constitute the upper arch of the waveform, and parts 3-5 the lower one.

3.EXPERIMENTS

short duration tones

The fact that the pitch of sustained tones with vibrato equates the arithmetic mean of the upper and lower values is taken for granted [Schonle & Horan]. This relation does not hold for short duration tones, particularly for notes with a non-integer number of pulsation cycles. The vibrato waveforms of Fig. 2 were presented to subjects. Series a and b have one and a half cycles and series has a half c of cycle. The subjects' responses clearly show that pitch is higher for $a1$ $a2$ $a3$ than for $b1$ $b2$ $b3$. The arithmetic mean is not significant in this case, but the pitch P can be linked with the mean value of the vibrato excursion $V(t)$ as a function of time, in the interval $[\alpha, \beta]$ of the tone duration.

$$P = \frac{1}{\beta - \alpha} \int_\alpha^\beta V(t)dt$$

For instance, we tried to equate the pitch for $a3$ and $b3$. Fig. 3 shows the f_0 values obtained, with which every subjects agreed. The inflexion direction (rising or falling) *is not perceptually relevant* for these isolated short duration notes. Short duration notes with vibrato occur frequently in actual soprano virtuoso performance. In our numerous observations, we only found the upper arch type of vibrato waveform for short duration notes. Fig. 4 shows such an example sung by Maria Callas.

pitch transition for tied notes with vibrato

We studied, by spectrographic analysis, a large number of arpeggio and scales extracted from works of lyric repertory. As W.Vennard remarked [Vennard 67], "a good singer sets the tempo in multiples of his vibrato". If tempo is imposed, a singer can speed up or slow down the rate of his vibrato, in order to *always keep an integer number of vibrato cycles in a note*. We investigated short duration transitions (one cycle per note), and longer transitions (many cycles per note).

short duration transitions

We synthesized several examples of diatonic and chromatic scales, intervals of third and fourth, ascending and descending. Listening to these examples actually shows that the transition is found acceptable when it begins with an half-arch in the direction opposite to the melodic movement: the lower one for an ascending interval, and the upper one for a descending interval. Consider the ascending third $si4 - ré4$. Figure 5 shows the fundamental frequency excursion for (a) a transition beginning at point 1, and (b) a transition beginning at point 3. Example (a) is found unprecise and weak while example (b) is judged in tune, unequivocally. Fig. 5c shows the performance from Mado Robin: the transition is similar to (b).

long duration transitions, portando and tied notes

To add expression, a singer can make a long duration transition, be perceived like a portando depending on the character of the piece. When vibrato occurs during the transition, many cycles can be observed between the two notes of the transition . H. Seashore [Seashore 35] first made this observation. The question is how these cycles will be perceived, since they do not differ from those encountered during rapid scales or arpeggio. In the last case, each cycle is perceived as a "note". Fig.6 shows an example from (a) Marilyn Horne, (b) Teresa Zilis-Gara. We made three stimuli from example 6+ shown in Fig. 7:

- isolation of the transition (7a): all the subjects perceived three chromatic descending notes (*la, lab, sol*).

- listening to the whole transition (7b): Chromatic notes disappeared. Between *la* and *sol* an expressive portando is perceived.

- listening to a fragment of descending chromatic scale (7c) including transision 7a. Every note is clearly identified.

The perception of tones with vibrato is therefore duration dependant. According to the context, a vibrato cycle can be completely ignored, or precisely identified as an independent tone.

4.CONCLUSION

This paper reports several experiments in the perception of vocal pitch vibrato during pitch transitions. The following results of listening tests have been obtained: first, for short duration staccato notes pitch is linked to the mean of the frequency excursion, independent of the waveform. Second, for tied notes, phase of the waveform seems to play an important role. Third, depending on the context, the same cycles of vibrato may be perceived as a transition only (*portando*) or independent notes. We will illustrate this results by playing some examples.
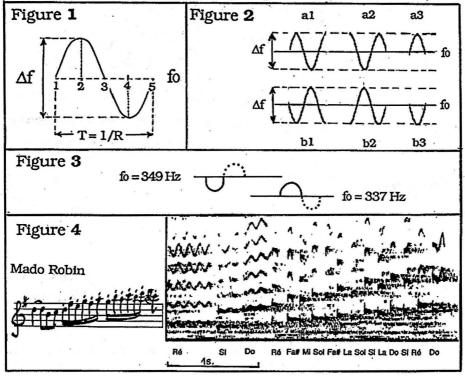
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Figure 1

Figure 2

Figure 3

Figure 4

Mado Robin

Figure 5

Ré

Si

a

b

c

Mado Robin

Figure 6

a

Marilyn Horne

b

Teresa Zylis-Gara

Ré3   portando   Lab4

1s.

La   Mi   Fa#   La   Sol

Figure 7

a

b

portando

c