PERCEPTION OF SELECTED MUSICAL INTERVALS IN FULL FREQUENCY RANGE

Andrzej Rakowski, Piotr Rogowski, and Elzbieta Aranowska
Chopin Academy of Music, Warsaw, Poland

ABSTRACT

Two experiments were performed with separate groups of subjects. In Experiment I twelve music students tuned the frequency of 500-ms pure-tone pulses to obtain upward-directed melodic intervals of a major second, a fifth and an octave as well as the interval of a prime (a unisone). Those intervals were produced in relation to standard tones located in vicinity of 9 nominal frequencies covering the pitch range from 32 to 6000 Hz. Every subjects tuned each of the 4 intervals 10 times in random succession in each of the 9 frequency ranges. All tones were presented via earphones, binaurally, with loudness level 40 phons. The results confirm the earlier findings that large context-free within-octave melodic intervals require to be produced larger and small intervals to be produced smaller than their corresponding equally-tempered values, and that this tendency holds across most of the hearing range.

In Experiment II another group of 16 music students tuned variable tones to produce pitches twice larger and a group of 15 music students tuned them to produce pitches twice smaller than those of standard tones located in 9 frequency ranges, same as in Experiment I. It appears that musicians, even when instructed that the task has no correlation with musical intervals, are unable to understand the procedure of doubling and halving pitch as different from setting an octave interval.

1. INTRODUCTION

Investigations on musical intervals were conducted so far mostly within the central part of a hearing range [1, 2, 3, 4]. It was intriguing to learn whether some earlier observations on a constant tendency of some context-free melodic intervals to be produced as smaller or larger than their tempered value holds across the whole hearing range or whether it is limited to the central part of a musical scale. Answering to this question was based on the results of Experiment I. It was also possible to formulate a new hypothesis concerning the much-discussed problem of octave stretching [5].

Experiment II was designed to shed some additional light on a somewhat different but still more import problem; that of the relations between musical and psychological scale of pitch. In the opinion of Stevens and his colleagues the difference between these two scales is fundamental [6, 7]. To verify such opinion, in Experiment II the results of tuning a melodic octave were compared with those of doubling and halving pitch across the whole frequency range.

2. EXPERIMENT I

2.1. Method

Twelve music students served as subjects in the experiment. They had otologically normal hearing and did not have absolute pitch. Their task was to tune 4 melodic intervals; upward-directed major second, fifth, and octave, as well as a prime. They were produced ten times in random order. This task was repeated in 9 randomly ordered frequency ranges marked by nominal frequencies 32, 63, 125, 250, 500, 1000, 2000, 4000, and 6000 Hz. The actual standard frequency (the lower frequency of a melodic interval) was chosen randomly for every tuning within ±200 cents from each nominal frequency. All stimuli were 500-ms pure-tone pulses with 20-ms attack/decay times, presented to listeners via high-quality earphones diotically with loudness level of about 40 phones. The listener could select standard or variable tone at wish and regulate frequency of a variable tone with a precise continuous regulator.

2.2. Results and discussion

Median results of 120 tunings (12 subjects, 10 replications) of each interval at every nominal frequency are shown in Figure 1. It can be seen that well-known tendency to enlarge an octave interval appears in most part at the hearing range and its magnitude is about 10 cents. Its maximum at 2 kHz (around C4) is well known to piano tuners. For frequencies outside piano range the enlarging effect suddenly disappears.

The enlarging effect may also be seen at tuning the fifth, as well as diminishing effect is seen in tuning a major second. This seems to be part of the general tendency to increase large and decrease small within-octave intervals. That tendency is strongly marked at middle frequency range in such intervals as sixths and sevenths, as reported by Rakowski and Miskiewicz [4]. The general conclusion from the present and from some previous reports is that octave enlargement effect is neither due to partial masking between first and second partial of a harmonic spectrum [8], nor to purely physiological effect of time delays in neural firings [9], but due to a general psychological tendency to stretch all large musical intervals.

Interquartile ranges of all sets of tuning are shown in Figure 2. As can be seen in the figure, accuracy of tuning all the intervals is strongly related to the accuracy of tuning the prime, or, in other words, to frequency-discriminating power of the ear.

ISBN 3-931852-67-9
ISSN 1617-6847

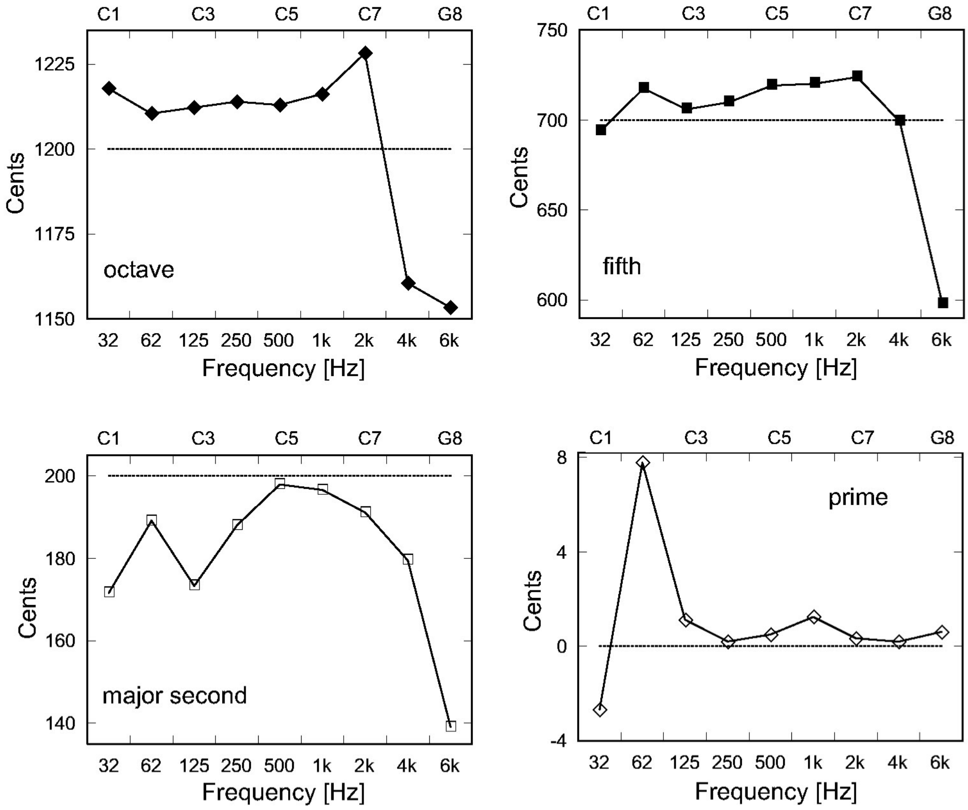

Figure 1: Medians of the results of tuning pure-tone melodic intervals upward (excluding a prime), from standard tones of nominal standard frequencies shown in the abscissa. Each point represents 120 tunings (12 subjects – music students, 10 replications). Actual standard frequencies were randomized within ±200 cents around nominal ones. Loudness level of all stimuli was kept constant at about 40 phones.

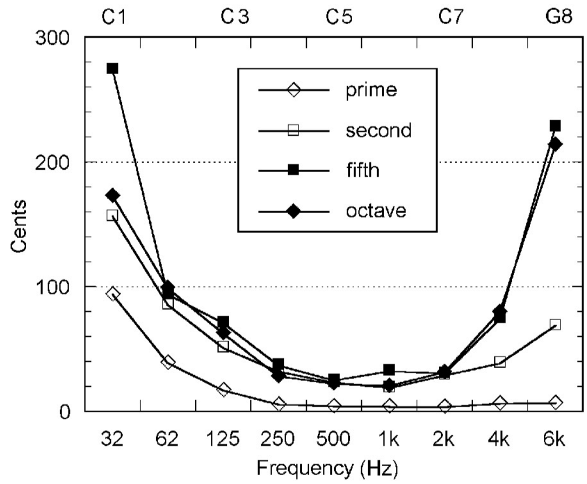

Figure 2: Interquartile ranges of the results of tuning pure-tone melodic intervals upward from standard frequencies shown in the abscissa. Each point represents 120 tunings.

3. EXPERIMENT II

3.1. Method

Sixteen students of music academy who did not participate in the previous experiment and ten university students (with no musical background) served as subjects in Experiment II. All of them had otologically normal hearing and no absolute pitch. The task of music students was divided into three separate parts. First, the subjects were asked to tune the frequency of a variable tone in such a way that its pitch was exactly doubling the pitch of a standard tone. They were carefully instructed to forget musical intervals and perceive the value of pitch like brightness of light or loudness of sound. Each of the subjects produced one setting of double pitch to 9 standard frequencies in random order within the range 32-6000 Hz. After that part of the task was completed by all the musicians, they were asked to tune variable tones one octave higher than standard ones. Third part of the task of the musicians, which was performed several weeks after the second one, was to tune pitch of a variable tone at half value of the standard pitch in 9 frequency regions within the range 63-12000 Hz. This part of the task was performed by 15 subjects.

The non-musical subjects, who were not aware of the concept of an octave participated only in the tasks of tuning the variable tones at double pitch value in relation to 9 standard tones. There was only one tuning to each standard frequency. All the technical conditions in Experiment II were the same as those in Experiment I.

ISBN 3-931852-67-9
ISSN 1617-6847

3.2. Results and discussion

Median results of tuning the pitch of variable tones upward from the standards are shown in Figure 3. The results of musicians are shown as circles, those of non-musicians as triangles. As seen in the figure, in most of frequency range there is practically no difference in the musicians' results for octaves (filled circles) and for double pitch (unfilled circles). One-way analysis of variance in the repeated measures design does not yield significant differences as to matching by musical subjects their octave tunings to the interval of a physical octave 2:1 on the levels of nine different frequencies [F (8,120) = 1,36; no–sig.]. Similarly, there are no significant differences with physical octaves on the levels of nine different frequencies in tuning by musicians a double pitch value [F (8,120) = 1,27; no–sig.]. Two-way analysis of variance in the repeated measures design in which nine levels of frequencies were treated as first factor, and the object of tuning (upper octave or doubled pitch) as second one does not yield statistically significant results. For the first factor value of F was equal: F (8,120) = 1,31; no–sig. For the second factor: F (1,15) = 0,005; no–sig. And for the interactions: F (8,120) = 1,32; no–sig. T-test for the paired samples shows no significant differences in any pair of means.

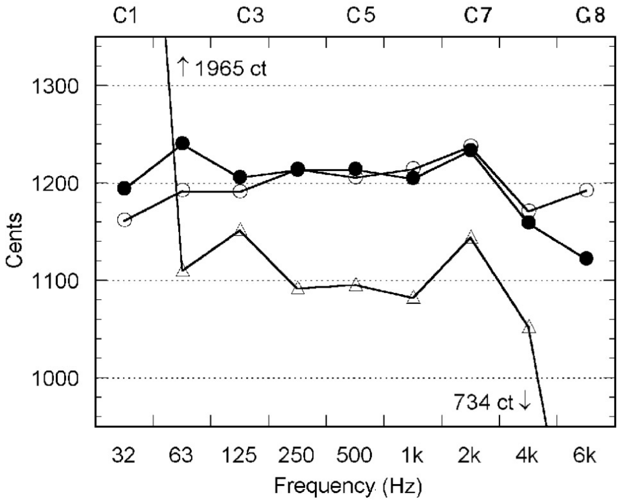

Figure 3: Medians of the results of tuning pure-tone pitch distances upward from standard frequencies shown in the abscissa. Circles – each point represents a group of single tunings by 16 music students whose task was to tune either a 2 times larger pitch value (unfilled circles) or an octave interval (filled circles) from the pitch of a standard-frequency tone. Triangles – each point represents a group of single tunings by 10 non-musicians whose task was to double pitch of each standard-frequency tone.

The results of non-musicians tuning double values of pitch are not very different from those of musicians. In most of the frequency range results approach the interval of a major seventh (1100 cents).

Figure 4 shows the results of tuning variable tones at half value of the pitch of standard tones whose frequencies are shown in the abscissa. Fifteen music students took part in the experiment. These results seem to indicate that musicians, even when instructed to forget musical intervals, nevertheless understand half pitch as an interval one octave downward.

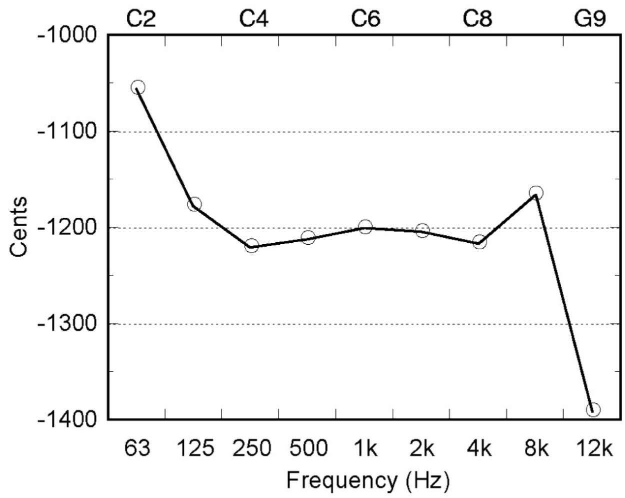

Figure 4: Results of tuning the pitch of pure tones by halving the pitch of standard tones. Medians of single tunings by 15 music students are shown as distances in cents from 9 standard frequencies.

4. GENERAL CONCLUSIONS REFERRING TO SCALES OF PITCH

Results of the present experiment in connection with those of some previous ones seem to shed some new light on the properties and meaning of the octave interval. At first, its systematic enlargement by about 10 cents appearing in most part of the frequency range must be part of a general psychological tendency to stretch large musical intervals. Next, constant recognition by musicians of an octave as a pitch distance for doubling and halving pitch leads to considering that particular interval as definitely more than "the most important musical interval". It reminds of a basic physiological fact of a synchronism between a periodic sound vibration and a series of neural pulses in an auditory nerve, leading to neural concordance between two periodic stimuli with doubling frequencies.

In view of those facts the existence of a psychological pitch-ratio scale, or, more generally a pitch-distance scale that could neglect the ratio 2:1 as its base appears rather unrealistic. Still, it should be remembered that a psychological pitch-distance scale and a psychological scale of pitch value are two qualitatively distinct phenomena, and the latter can hardly be constructed by investigating, the relations between pitches. The only way to produce a true scale of pitch as a psychological magnitude (pitch value) seems to be by the method of absolute magnitude estimation [10, 11].

ISBN 3-931852-67-9
ISSN 1617-6847

5. REFERENCES

1. Moran, H. and Pratt, C. C. (1926). Variability of judgments of musical intervals. *Journal of Experimental Psychology, 9, 492-500.*

2. Shackford, C. (1961). Some aspects of perception, Part I: Sizes of harmonic intervals in performance. *Journal of Music Theory, 6, 66-90.*

3. Dowling, W. J. and Bartlett, J. C. (1981). The importance of interval information in long-term memory for melodies. *Psychomusicology, 1, 30-49.*

4. Rakowski, A. and Miskiewicz, A. (1985). Deviations from equal temperament in tuning isolated musical intervals. *Archives of Acoustics, 10, 95-104.*

5. Hartmann, W. M. (1993). On the origin of the enlarged melodic octave. *Journal of the Acoustical Society of America, 32, 1575-1581.*

6. Stevens, S. S., Volkmann, J. and Newman, E.B. (1937). A scale for the measurement of the psychological magnitude pitch. *Journal of the Acoustical Society of America, 8, 185-190.*

7. Stevens, S. S. and Volkmann, J. (1940). The relation of pitch to frequency: A revised scale. *American Journal of Psychology, 3, 329-353.*

8. Terhardt, E. (1971). Pitch shift of harmonics, an explanation of the octave enlargement phenomenon. *Proceedings of the 7th International Congress on Acoustics*. Budapest 1971, 621-624.

9. Ohgushi, K. (1983). The origin of tonality and a possible explanation of the octave enlargement phenomenon. *Journal of the Acoustical Society of America, 73, 1694-1700.*

10. Rakowski, A. (1997). Musical and psychological scales of pitch. In: A. Preis and T. Hornowski (eds), *Fechner Day 97*. Poznan Editions, Poznan.

11. Rakowski, A. and Miskiewicz, A. (1998). Pitch of pure tones measured by absolute magnitude estimation. *Proceedings of the 16th International Congress on Acoustics*. Seattle 1998, 161-162.

ISBN 3-931852-67-9
ISSN 1617-6847