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TOLERANCE OF INTONATION DEVIATION IN MELODIC INTERVALS IN LISTENERS OF DIFFERENT MUSICAL TRAINING

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The aim of the present experimental paper was to investigate the tolerance of intonation deviations in musical intervals, depending on listeners' musical training. The investigations covered the perception of intonation deviations of chosen melodic intervals in isolation and in melodic context. Tests were edited from music material recorded on magnetic tape and were exposed by a loudspeaker to groups of 8 - 12 persons. The results obtained confirmed a dominating effect of musical training on the tolerance of intonation deviations in isolated intervals and those in melodic context. It was found out that in a musically trained group the tolerance of intonation deviations in intervals in melodic context was influenced by functional tendency and by the direction of intervals in a musically untrained group.

1. Introduction

In 1924-1925 Moran and Pratt [14] initiated investigations, aiming at determination of musical interval sizes in a psychoacoustic sense. Establishing the variability range of an interval tuned freely under the conditions of listeners adjusting the frequency of one of tones with respect to a constant reference tone, intonation tolerance zones of the particular intervals were obtained. For intervals of less than octave these zones were 13 - 22 ct.

In more recent papers a similar direction of investigation was followed by Ward [26], Drobner [4], Tarnoczy and Szende [25], Sundberg and Lindqvist [24], Ossolińska-Sieńczewska [17], Lippus, Remmel and Ross [12], and Rakowski [20]. These research workers confirmed that interval estimation is based on a sensation of its size, which does not always coincide with frequency ratio estimation. All of the above mentioned investigations were performed on isolated intervals. The experiments consisted in free tuning of an interval or estimation of its magnitude.

Apart from this direction, intonation was investigated on the basis of instrumental and vocal recordings of parts of pieces of music. In his investigation of melodic intervals on the basis of a gramophone recording of Violin Etude No. 2 by Kreutzer, GREENE [7] found out that the dominating intonation pattern is one close to the Pythagorean system. The same conclusion was also reached by NICKERSON [15]. It was GARBUZOV's investigation [6] of intonation that proved that the key in which vocal and instrumental pieces in untempered system are performed is a twelve-zone system, and the pitch of a musical sound, symbolized by a discrete value of frequency, is psychologically a pitch zone of some width. The zonal theory of GARBUZOV was further developed in investigations of the interval intonation in melodic structures carried out by RAGS [19] and SAKHALTUEVA [21, 22] and works of BURNS [1], BURNS and WARD [3], and in RAKOWSKI [20], devoted to a categorical perception of intervals. RAGS and SAKHALTUEVA tried to grasp and explain the regularity of intonation deviations occurring in the performance of a melody on instruments of untempered system. They have found that clear intonation is a variable quantity closely related to a tonal design of a piece and to the creative purposes of the artist. Being one of elements of musical expression, intonation is specifically related to a whole series of elements of a piece of music: the design of melody, harmony and rhythm, dynamics and elements of musical form.

The results of these investigations have proved that a musical context is a dominating cause of intonation deviations. The effect of musical context on the perception of intervals was also stressed by other research workers: FRANCÈS [5], SHACKFORD [23], LEIPP [11], PATTERSON [18], HARAJDA and FYK [8], WRONKOWSKA [27].

A common feature of the previous investigations in the field of interval perception was the participation in these investigations of listener groups uniform in terms of musical training and most frequently highly trained. The conclusions drawn from these investigations applied, therefore, only to this narrow listener community. On the basis of the previous investigations [16, 10, 2, 13, 3, 20], which stressed the role of musical training and showed that the perception of intonation deviations in intervals was conditioned by previous practice, qualitative differences in the perception of interval intonation deviations of the same size could be expected in listeners representative of different musical training.

Detection and analysis of these differences was the aim of the present paper, and since there are only a few papers on a joint investigation of the perception of intervals in isolation and in melodic structures [8, 9, 27], the author decided to make comparisons also in this respect. However, with its present limited investigation material, this paper does not aim to explain fully the reasons for these differences and the laws which governed them. It presents only an initial stage of this investigation.

The investigations were performed for chosen melodic intervals in isolation and in melodic context. The following isolated intervals were used: prime (1), minor second intoned upwards ($2m\uparrow$), major second intoned downwards ($2w\downarrow$) and minor third intoned downwards ($3m\downarrow$). The first three intervals and also a major seventh ($7w$) were investigated in melodic context. 1,*2m*, *2w* and *3m* were selected, since these intervals most frequently occur in melodies and, to a large extent, are melody components, which was confirmed by ORTMANN's investigations [16]. *7w* was selected as an interval in strong contrast to features of the intervals mentioned above.

Since intervals in a melody are elements of some superior whole, it is important to select a melodic context which favours the individualization of intervals, i.e. which permits a diversity of intonation deviations. Melodies composed for this purpose included intervals built from degrees of low intonation stability (IInd and VIIth degrees of the scale).

2. Criteria for selection of the group

The experiment was performed on three first-year students of pedagogy departments of Pedagogical University, Zielona Góra. Selection of students to the particular groups was based on their musical training. Additionally, the following criteria were applied to all persons participating in the experiment: otolaryngologically normal hearing and good intonation accuracy. Hearing was examined audiometrically twice and the curves of the audibility threshold were determined separately for each ear. Only those persons in whom the hearing loss did not exceed the medical norm participated in these experimental investigations. Examination of intonation accuracy permitted persons having difficulties with clear intonation (13 persons) to be eliminated. Most of these were found to have a high pitch discrimination threshold (of about 10 Hz for a reference frequency of 440 Hz). Eventually, 20 students of the Pre-School Pedagogy Department without any musical training were assigned to the first group. The second group of 30 persons was made up of the Initial Education Department who had learned to play an instrument for two to four years (except one, all the listeners had graduated from secondary level schools for kindegarten personnel). The third group of 20 persons included students of the Musical Education Department with seven years on average of musical training. The listeners in the above groups took part in listening tests of the tolerance of intonation deviations in intervals in isolation and of those in melodic context.

3. Composition of tests

The tests were developed for sinusoidal tones (the test of the tolerance of intonation deviations in isolated intervals) and for piano sounds (the test of the tolerance of intonation deviations in intervals in melodic context). Detailed data on the programming of a test of sinusoidal tones were given in the description of an earlier experiment devoted to the investigation of the perceptibility of mistuned melodic intervals in secondary school students [9]. The test made up of piano sounds was also recorded under analogous conditions and using the same measurement apparatus as in the experiment mentioned above.

3.1. *The test of the tolerance of intonation deviations in isolated intervals consisted of 4 series*. The first series concerned the tolerance of intonation deviations of the prime (1); the second series – the minor second intoned upwards (2*m*↑), the third – the major second intoned downwards (2*w*↓), and the fourth series – the minor third intoned downwards (3*m*↓). Each series included 12 pairs of intervals, of which, in 10 pairs, the first interval was the standard one, while the second interval called the variable interval showed intonation deviation in the second sound of the interval; in the other two pairs only intervals without intonation deviations (standard intervals) occurred. The standard interval of a given interval was an intonation variant of the interval which corresponded to the size of the interval in a well-tempered system. The sizes of intonation deviation were 10, 15, 25, 50 and 75 ct, upwards and downwards. In order to make possible the comparison of the tolerances of intonation deviations in intervals in isolation and in melodic context, in both cases the same direction and pitch register of an interval were maintained, with, however, a basic difference: the second interval in a pair of isolated intervals was not transposed, while the second melody of a test pair which contained a variable interval was transposed. Test tasks were presented in an almost stochastic order. The listeners' task was to estimate whether there was a perceptible difference between the intonation of the second sound in the standard interval and that of the variable interval.

3.2. *The test of the tolerance of intonation deviations in intervals in melodic context consisted of 7 series comprising test melodies with the following intervals included*: series I – the prime which was a repetition of the lower keynote (1 I → I degree), series II – the minor second in direction from VII to VIII degree (2*m* VII → VIII), series III – the minor second in direction from VIII to VII degree (2*m* VIII → VII), series IV – the major second in direction from I to II degree (2*w* I → II), series V – the major second in direction from II to I degree (2*w* II → I), series VI – the major seventh in direction from VII to I degree (7*w* I → VII), series VII – the major seventh in direction from VII to I degree (7*w* VII → I). Each series consisted of 20 pairs of a two-bar melody in major key. The first melody was the standard, while the other was a transposition of the former by an interval of 2*w* upwards. The second melody was transposed with respect to the standard so as to avoid the listeners comparing the final sounds of both melodies in terms of pitch instead of interval size. In the transposed melody every second case featured intonation deviation in the last sound, whose size was, respectively, 5, 10, 15, 25 and 50 ct upwards and downwards. A pair of melodies composed of the standard and the transposed melody constituted one test task. An example of the test task is shown in Fig. 1.

The intervals *2m*, *2w* and *7w* always occurred in two melodic contexts: in the first one the melody defined the harmonic content finished with a cadence,

Fig. 1. An example of a test task in series I of the test of the tolerance of intonation deviations in intervals in melodic context

melody *s* — the standard melody, melody *t* — the transposed melody, p^1 — the pause between a pair of melodies, p^2 — the answer time

Fig. 2. Music material of successive series of the test of the tolerance of intonation deviations in intervals in melodic context

melody *s* — the standard melody, melody *t* — the transposed melody, I, II, VII, VIII — degrees of a major key. In brackets variable intervals and in the second one with a semi-cadence. Application of intervals in different melodic contexts served to show the influence of the interval harmonic tensions in a melody, which resulted from the harmonic tendency, on the tendency and tolerance of intonation deviations. Music material of the successive test series is shown in Fig. 2.

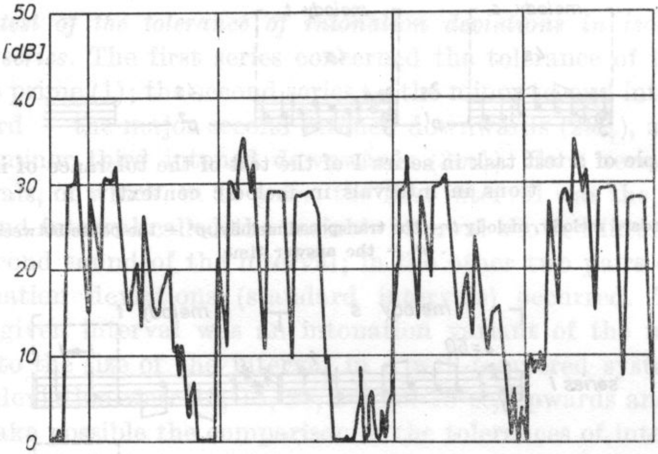

Fig. 3. The time behaviour of amplitude in two successive tasks in series I of the test of the tolerance of intonation deviations in intervals in melodic context

Fig. 3 shows amplitude changes in the course of two successive test tasks performed on the piano. The test melodies ended with a prime interval (1 I → I) without intonation deviation. They were recorded by a PSG-101 recorder. It can be seen that the amplitude variability range of the interval investigated did not exceed 2 dB.

After listening to each pair of melodies the task was to estimate whether there is a perceptible difference between the intonation of the final sound in the standard and that of the transposed melody. The tests were presented from a tape recorder by one loudspeaker column facing the listeners. The sound reproduction level of the test of sinusoidal tones varied from 40 to 60 phons and that of piano sounds from 60 to 70 phons. The listenings of the tests were performed in groups of 10 to 12 persons.

4. Analysis and discussion of the results

The results of the investigation of the tolerance of intonation deviations in intervals in isolation and in melodic context were represented by psychometric curves. Fig. 4 shows the psychometric curves of three listener groups for the isolated intervals 1 and $2m\uparrow$, while Fig. 5 shows these also for the isolated intervals $2w\downarrow$ and $3m\downarrow$. The psychometric curves of three listener groups for

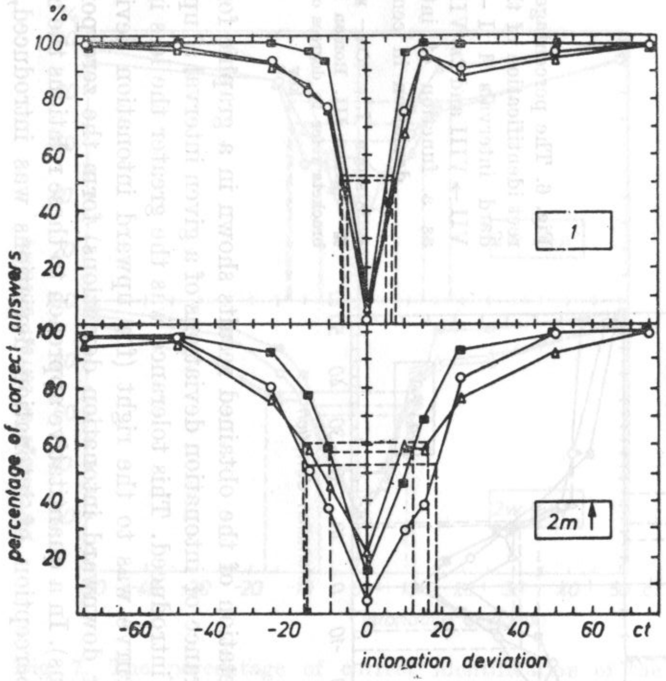

Fig. 4. The percentage of correct identification of the standard intervals of the prime (1) and the minor second intoned upwards ($2m\uparrow$) as a function of intonation deviation in cents

△ – group I, ○ – group II, ■ – group III

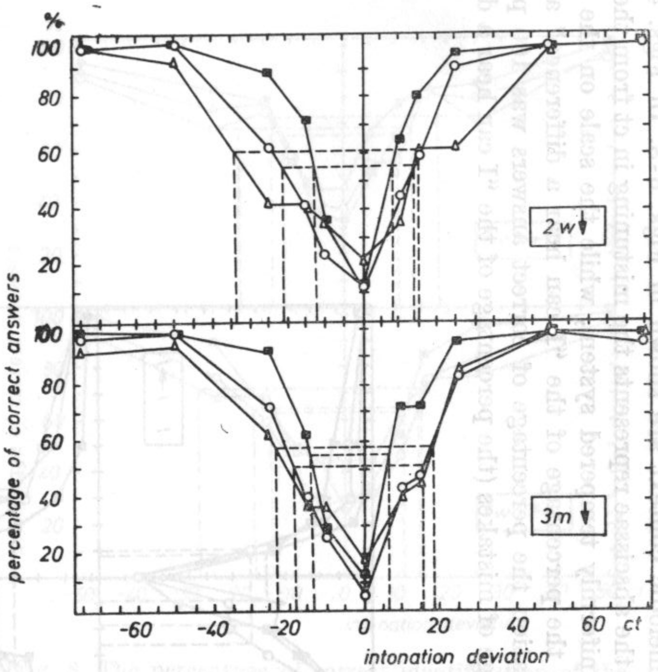

Fig. 5. The percentage of correct identification of the standard intervals of the major second intoned downwards ($2w\downarrow$) and of the minor third intoned downwards ($3m\downarrow$) as a function of intonation deviation in cents

△ – group I, ○ – group II, ■ – group III seven intervals in melodic context are shown in Figs. 6-8. In Figs. 4-8 the scale on the axis of the abscissae represents the mistuning in ct from the values determined by a uniformly tempered system, while the scale on the axis of the ordinates gives the percentage of the "I can hear a difference" answers. For a lack of deviation the percentage of correct answers was 100 per cent minus the percentage of mistakes (the percentage of the "I can hear a difference" answers).

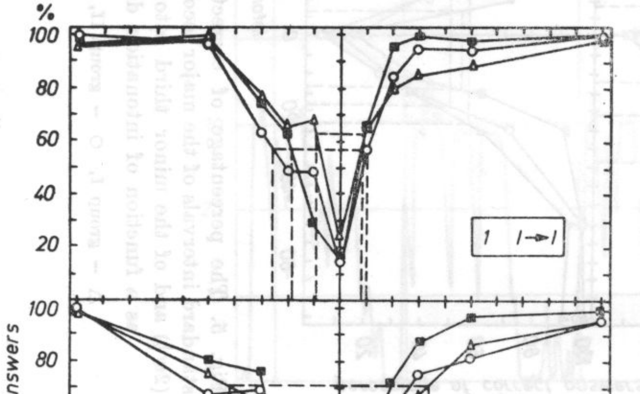

Fig. 6. The percentage of correct identification of the standard intervals 1 I → I, 2m VII → VIII and 2m VIII → VII as a function of intonation deviation in cents

△ – group I, ○ – group II, ■ – group III. Roman letters in brackets refer to degrees of a major key

In the interpretation of the obtained results shown in a graphic form the concept of the tolerance of intonation deviations of a given interval a) upwards, b) downwards was introduced. This tolerance was the greater the less inclined the psychometric curve was to the right (for upward intonation deviations) and to the left (for downward intonation deviations) form the zero point (no intonation deviations). In a quantitative approach to these relations the concept of the threshold perception of intonation deviations was introduced, being

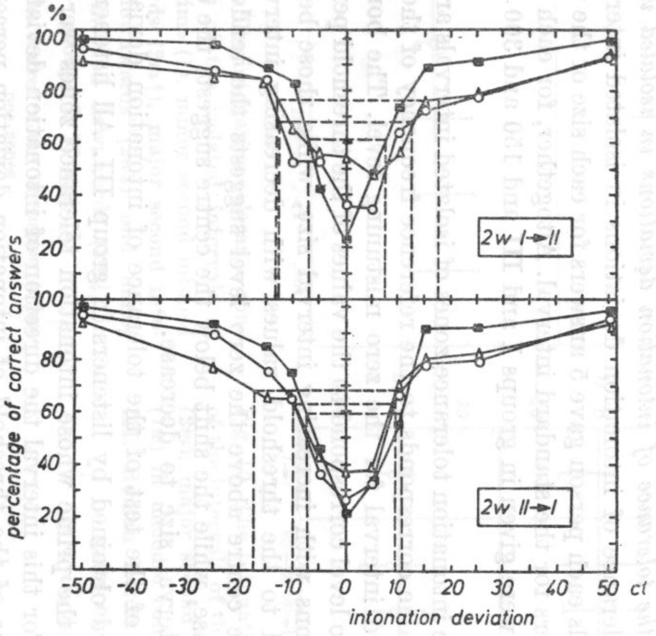

Fig. 7. The percentage of correct identification of the standard intervals 2*w* I → II and 2*w* II → I as a function of intonation deviation in cents

△ – group I, ○ – group II, ■ – group III. Roman letters in brackets refer to degrees of a major key

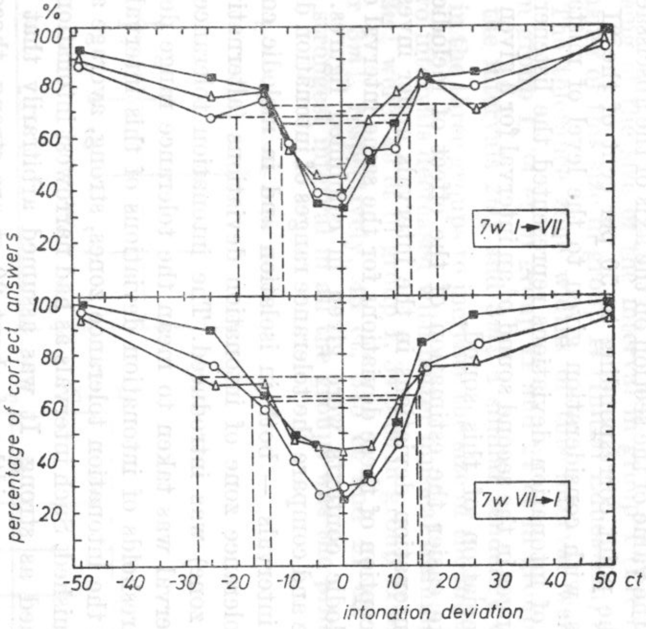

Fig. 8. The percentage of correct identification of the standard intervals 7*w* I → VII and 7*w* VII → I as a function of intonation deviation in cents

△ – group I, ○ – group II, ■ – group III. Roman letters in brackets refer to degrees of a major key defined arbitrarily as the value of the section on the axis of the abscissae between the zero point and the point corresponding to 50 per cent of the "I can hear a difference" answers, with consideration given to the level of mistakes. The threshold perception of intonation deviations represented the listeners' ability of detecting pitch changes in the second sound of an interval for a given direction of the intonation deviation of this sound.

In order to make easier the estimation of the effect of melodic context on the tolerance of intonation deviations in the intervals under investigation, the results of the perception of these deviations for the same interval occurring in two different melodic contexts were given in combined figures.

In order to define and compare the tolerance ranges of intonation deviations in standard melodic intervals — both in isolation and in melodic context — the concept of the tolerance zone of intonation deviations (alternatively, the intonation tolerance zone) was introduced. The intonation tolerance zone of a given standard interval was taken to mean the tolerance range determined by the perception thresholds of intonation deviations of this interval. On the basis of the width of the intonation tolerance zones, strong, average and weak intervals were distinguished. Such intervals as had narrowest intonation tolerance zones were assumed as strong. It was assumed arbitrarily that intervals of intonation tolerance zone widths of about 20 ct are strong, those of zone widths of about 25 ct are average and those of zone widths exceeding 30 ct are weak.

4.1. *Analysis of the tolerance of intonation deviations in isolated intervals.* In the test of the tolerance of intonation deviations in isolated intervals for the particular intervals each person gave 5 answers for each size of the variable interval and 10 answers for the standard interval. Altogether, for each interval 100 and 200 answers were given in groups I and III and 150 and 300 answers in group II.

The widths of the intonation tolerance zones of isolated intervals are shown in Fig. 9. The zero value corresponds to the reference frequency of the second sound of the standard interval for the zero mistuning level. The boundaries of zones above the zero level correspond to the values of the threshold perception of intonation deviations with increasing interval size, while those below the zero level correspond to the threshold values with decreasing interval size. The shift of the zone centre above the zero level suggests the tendency for interval size to increase, while the shift below the centre suggests the opposite tendency, i.e. for interval size to decrease.

The best results of the test of the tolerance of intonation deviations in isolated intervals were obtained by listeners in group III. All listeners found it easiest to perceive the prime whose intonation tolerance zones were in the limits 14.5-10.5 ct. For this interval the direction of intonation deviation had no effect on the value of the threshold of intonation deviation perception.

Two opposite tendencies were observed to occur in the interval $2m\uparrow$: a decreasing of the size of the interval in group I (Pre-School Pedagogy) and an increasing of this size in group II (Initial Education) and III (Musical Education). The tolerance zone widths of this interval were different and were 28.5 ct in group I, 34 ct in group II and 21 ct in group III.

For the intervals $2w\downarrow$ and $3m\downarrow$ a similar tendency could be observed for listeners in the three groups to increase the size of the intervals. The zone widths of the two intervals decreased with better musical training of persons examined and for $2w\downarrow$ were: 49 ct in group I, 34.5 ct in group II and 21 ct in group III, while for $3m\downarrow$, respectively, 43 ct, 345 ct and 21 ct.

The strongest interval in all the groups was the prime the narrowest into-

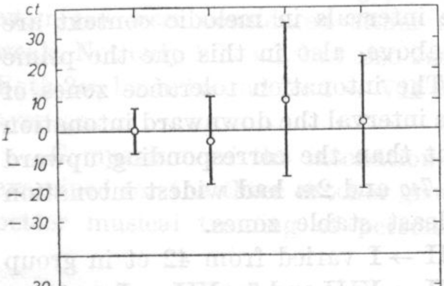

Fig. 9. The intonation tolerance zone widths of the isolated intervals of the prime (1), minor second intoned upwards ($2m\uparrow$), major second intoned downwards ($2w\downarrow$) and minor third intoned downwards ($3m\downarrow$) in groups I, II and III

○ – the centres of the intonation tolerance zones

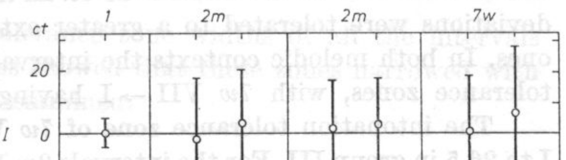

Fig. 10. The intonation tolerance zone widths of the intervals of the prime (1), minor second (2m), major second (2w) and major seventh (7w) in melodic context in groups I, II and III. Roman letters in brackets refer to degrees of a major key

○ – the centres of the zones

nation tolerance zone. In group III the strong intervals were all the other intervals, i.e. $2m\uparrow$, $2w\downarrow$ and $3m\downarrow$, while the same intervals were weak in groups I and II.

4.2. *Analysis of the tolerance of intonation deviations in intervals in melodic context.* In the test of the tolerance of intonation deviations in intervals in melodic context, for the particular intervals each person gave 5 answers for each of 10 intonation deviations in an interval and 50 answers for a standard interval. Thus, a total of 100 answers were obtained in groups I and III for each of the ten intonation deviations in an interval examined and that of 1000 answers for a standard interval. Analogously, 150 and 1500 answers, respectively, were obtained in group II.

The intonation tolerance widths of the intervals in melodic context are shown in Fig. 10. As in the test described above, also in this one the prime (1 I → I) was the most easily perceptible. The intonation tolerance zones of this interval were in the limits 9-18 ct. In this interval the downward intonation deviations were tolerated to a greater extent than the corresponding upward ones. In both melodic contexts the intervals *7w* and *2m* had widest intonation tolerance zones, with *7w* VII → I having least stable zones.

The intonation tolerance zone of *7w* VII → I varied from 42 ct in group I to 26.5 in group III. For the intervals *2m* VII → VIII and *7w* VII → I common trends in perception occurred in three listener groups: a decrease in the size of *2m* and an increase in the size of *7m*. These trends agreed with the results obtained by GARBUZOV [6], SAKHALTUEVA [21, 22] and SHACKFORD [23]. In addition the low stability of the intonation tolerance widths of the intervals *2m* VIII → VII and *7w* I → VII, which occurred in the present experiment, where the second sound is the VIIth degree of the key, confirms the SAKHALTUEVA's conclusion [21, 22] as to the considerable width of the intonation deviation zones of the VIIth degree of the key. For the interval *7w* I → VII "average thresholds" occurred in two listener groups. The values of these thresholds were obtained by averaging two threshold values for listeners in these two groups, i.e. 8 ct and 28 ct in group I and 14 ct and 27 ct in group II. The "average thresholds" suggested difficulties in perceiving *7w* I → VII caused by a weak memory trace of this interval, which thus prevents its exact identification. These difficulties were also pointed out by RAKOWSKI's investigations [20] on the differences between the manners of identifying strong and weak intervals (RAKOWSKI [20] distinguished between strong and weak intervals on the basis of the "interval strength" which he identified with the strength of the memory trace established in the long-term memory of listeners).

Different widths of intonation tolerance zones of the same interval when it occured in two different melodic contacts suggested that the context prevented the treatment of the size of a given interval only from one point of view, which agreed with the results of other authors [5, 9, 21, 22, 23, 27]. Considerable differences in the widths of intonation tolerance zones which occurred between different listener groups could be explained by the variously sensed activity of the second sound of the interval in a given melodic context. E.g. while in group I 7*w* I → VII was a weak interval, it was strong in group III. It seems that the increasing stability of the intonation tolerance zones of the intervals examined resulted from a stronger memory trace established in the listeners' memory, which was directly related with the intensity of musical training.

On the basis of the intonation tolerance zone widths 1 I → I was taken in group I as strongest, 2*w* I → II and 2*w* II → I as average, and both 7*w* and both 2*m* as weak. In group II 1 I → I was also strongest, 2*w* II → I strong, both 2*m* and 2*w* I → II average, and both 7*w* weak. In group III all the intervals examined were considered either strong or average, none being regarded as weak. Not only 1 I → I, but also 2*w* I → II were strongest in this listener group. Both 2*w*, both 2*m* and 7*w* I → VII were strong; only 7*w* VII → I was considered average.

Comparison of the intonation tolerance zone widths of all the intervals examined for the three listener groups showed that these zones narrowed with better musical training of persons examined.

5. Conclusions

On the basis of the data on the tolerance of intonation deviations in melodic intervals in isolation and in melodic context the following conclusions could be drawn:

1. Both in intervals in isolation and those in melodic context a dominating influence on the tolerance of intonation deviations from a standard interval was exerted by the musical training level of persons examined; the higher the musical training level was the lower was the tolerance of intonation deviations. These relations were represented by different intonation tolerance zone widths which decreased for listeners in groups II and III (Figs. 9 and 10).

2. General perception trends occurred for the isolated intervals 2*w*↓ and 3*m*↓, which consisted in the greater tolerance of intonation deviations in agreement with the direction of the motion of the interval. This is confirmed by the asymmetrical behaviour of the psychometrical curves of these intervals for all the listener groups (Fig. 5).

3. The tolerance of pitch hearing of intonation deviations of isolated intervals and that in melodic context were not the same. This could be seen in the greater tolerance of intonation deviations of the isolated prime (Figs. 4 and 9) and of the major second (Figs. 7 and 10), and in the lower tolerance of deviations in these intervals when in melodic context (1 I → I, Figs. 6 and 10, and 2*w* II → I, Figs. 7 and 10). For all the listener groups the prime was the stron-

gest interval both in isolation and in melodic context. Different widths of the intonation tolerance zones of intervals examined in melodic context permitted the distinction into strong intervals (both *2m* and *7w* I → VII in listener group III and *2w* II → I in listener group I), average intervals (both *2m* and *2w* I → II in listener group *7w* and both *2m* in listener group I) and weak intervals (both *7w* and both *2w* in listener group I). Of intervals in isolation, while the strong intervals in group III were *2m*↑, *2w*↓ and *3m*↓, the same intervals were weak in groups I and II.

4. In a musically trained group the tolerance of intonation deviations in intervals in melodic context was influenced by functional tendency, which led to a lowering of the Ist degree in the interval of the prime (1 I → I, Fig. 6) and a raise of the VIIth degree in the interval of the minor second (*2m* VIII → VII, Fig. 6), with a simultaneous lowering of the latter degree in a musically untrained group. In a musically untrained group the tolerance of intonation deviations is influenced considerably by the direction of interval motion, causing a lowering of the VIIth degree in the interval of the minor second (*2m* VIII → → VII, Fig. 6), to a lowering of the Ist degree in the interval of the major second (*2w* II → I, Fig. 7) and in that of the major seventh (*7w* VII → I, Fig. 8), and to a raise of the IInd degree in the interval of the major second (*2w* I → II, Fig. 7).

5. Comparison of the intonation tolerance zone widths of intervals in melodic context showed that the melodic context favoured differentiation in interval strength.

The quantitative and qualitative differences in perceptibility between musically trained and untrained listeners revealed here showed the important role of musical education in development of perceiving abilities.

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