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THE PERCEPTIBILITY OF MISTUNED MELODIC INTERVALS BY SCHOOL CHILDREN

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The aim of this study was to investigate the perceptibility of detuned (mistuned) melodic intervals of prime (1), minor second (2*m*), major second (2*w*) and minor third by school children, depending on the sound timbre and the age of persons examined. The investigation included isolated intervals and intervals in a melodic context. The results obtained for age groups from different centres were compared. It was found that a student of average musical talent tends to perceive detuned melodic intervals below a quarter tone. The perceptibility of these detunings is much higher in intervals composed of musical sounds ("coloured" sounds) occurring in a musical context than in isolated intervals composed of sinusoidal tones. The age of a student or the centre from which he comes were found not to have an effect on the perceptibility of the detunings.

1. Introduction

The perception of melodic intervals by groups of persons of high musical training were investigated by several researchers, WARD [14], DROBNER [3], TARNOCZY and SZENDE [13] and RAKOWSKI [11]. The investigations of this type performed on musically neglected children were described by LEWANDOWSKA [8]. There is a lack, however, of data obtained by acoustical investigation methods and related to the perceiving abilities of average gifted children. One of the basic conditions of sound pitch perception is the perceptibility of detuning (mistuning). A laboratory experiment was therefore conducted, which aimed at investigation of the abilities in this respect of children undergoing a general, nonprofessional musical training in school. The aim of the investigation was to determine the perceptibility of detunings of chosen melodic intervals below a semitone.

At the same time an attempt was made to investigate whether this perceptibility is related to the sound timbre and age of a child.

For this purpose, special tests composed of the following complex sounds were designed and made: piano sounds (called the pianoforte sounds, designated as *Pfp*), flute sounds (*Fl*) and violin sounds (*Vln*), called below as "coloured tests", and tests of sinusoidal sounds, defined in short as "sinusoidal tests". The coloured tests were used in three age groups including children from forms I and II (designated as I/II), III and IV (III/IV), and V and VI (V/VI). The pianoforte tests were used in all groups while the other were used only in groups III/IV.

Music material was taken from the repertory of songs in the school programme for the particular forms, i.e. from the following collections: Powroźniak [19], Lipska and Przychodzińska [17, 18], Przychodzińska [20], Stankiewicz [21, 22], Kaczurbina [6]. The coloured tests were used to investigate the perceptibility of detunings of the intervals in a melodic context, while the sinusoidal tests were used in the case of detunings of isolated intervals.

The psychological position of a sound in a melody is defined by its tonal context, its absolute position on the pitch scale and the course of the melody [9]. Investigations in this field showed that a listener is hardly aware of intervals in a melody since his attention centres on the melody as a whole instead [1], and the melodic line functions independently of the order of interval sizes [2]. Moreover, even the same intervals occurring in different musical contexts are not equal in the psychological sense. The effect of the musical context on the perception of intervals was stressed by Sakhaltueva [12], Chmielewska [1], Leipp [7], Harajda and Fyk [4]. Therefore, the melodic phrases making up the music material of the tests take into account the distinct functional character of intervals under investigation and also their position in a melody.

The following intervals were selected:

– for the group of children from forms I/II; F^1-F^1 (the functional degrees I→I), F^1 sharp-G^1 (VII→VIII), D^1-C^1 (II→I), C^2-A^1 (V→III);

– for the group of children from forms III/IV, G^1-G^1 (I→I), F^1 sharp-G^1 (VII→VIII), A^1-G^1 (II→I), G^1-E^1 (V→III);

– for the group of children from forms V/VI; F^1-F^1 (I→I), D^1-E^1 flat (VII→VIII), A^1-G^1 (II→I), E^2-A^1 (V→III).

The intervals 1, *2m*, *3w*, *3m* were selected, because these intervals most frequently occur in school musical texts.

The domination of short intervals over long ones in melody was already stressed by Ortmann [9], on the basis of analyzing 160 songs. This is also confirmed by the interval analysis of songs in music school-books. As an example, there were given results of the interval analysis performed on 45 songs contained in the currently used music school-book for form V [6].

The present experiment was carried out from 1976 to 1979 under laboratory conditions and was preceded by an experiment under natural conditions, in school. The children participating in both experiments represented the "average student group". The first experiment was to determine the abilities of perceiving

Table 1. The frequency of the occurrence of the melodic intervals in school songs in form V (45 melodies 2932 intervals)

Interval	Number	[%]	Interval	Number	[%]
1	579	19.8	4*zw*	9	0.3
2*m*	485	16.5	5*zmn*	19	0.7
2*w*	905	30.9	5	79	2.7
3*zmn*	1	0.0	6*m*	13	0.4
3*m*	402	13.7	6*w*	25	0.9
3*w*	218	7.4	7*m*	14	0.5
4*zmn*	1	0.0	7*w*	0	0.0
4	172	5.9	8	10	0.3

melodic intervals over an octave, within the solfeggio error, i.e. exceeding a semitone. It was carried out in groups of 8 to 15 persons in 24 centres, including 728 children. The centres included big cities (designated as *M*), small towns *m* and rural centres *W*. On the basis of carefully made subjective examinations by teachers and specially selected examiners, three children, the most representative ones for the "average student" level, were selected for the laboratory experiment from each group.

2. Composition of tests

a. Coloured tests. The composition of all the types of the tests is the same. They are composed of a set of tests presented in four series which correspond to the following intervals:

series I — prime (1), the repetition of the tonic,
series II — minor second (2 *m*) in direction VII→VIII degree,
series III — major second (2*w*) in direction II→I degree,
series IV — minor third (3*m*) in direction V→III degree.

Each of the series uses different musical-melodic material and is preceded by a longer and shorter piece of a given metody (Fig. 1). A series consists of

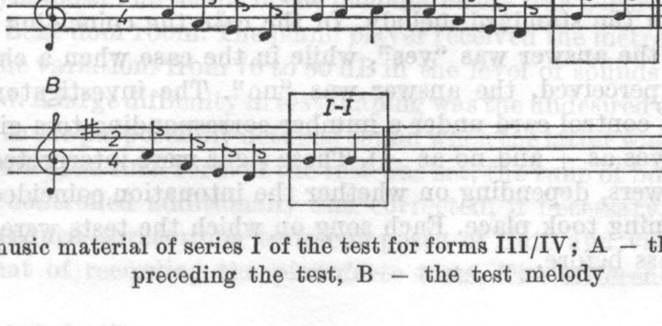

Fig. 1. The music material of series I of the test for forms III/IV; A — the piece of melody preceding the test, B — the test melody

12 pairs of a two-bar melody, i.e. of 10 pairs of melody pieces, which differ in the magnitude of the detuning of the last sound, and of 2 pairs in which the last sound is not detuned. In each pair the first melody is standard and not detuned while the second — the control melody — contains (in 40 cases) or does not contain (8 cases) a detuning of the last sound of a melody. Thus, each coloured test contains 48 tasks given in a quasi-stochastic order. The order of tasks in the pianoforte, flute and violin tests is given in Table 2. The detuning range

Table 2. The set of test tasks in pianoforte, flute and violin tests for the group from forms III/IV

Test task no	Detuning (ct)					
	pianoforte test		flute test		violin test	
1	+	100-75	+	100-75	+	100-75
2	—	50-25	—	50-25	—	50-25
3		0		0		0
4	+	50-25	+	50-25	+	50-25
5	—	15-10	—	15-10	—	25-15
6	+	25-15	+	25-15	+	25-15
7	—	100-75	—	100-75	—	100-75
8	+	25-10	+	15-10	+	15-10
9	—	75-50	—	75-50	—	75-50
10		0		0		0
11	+	75-50	+	75-50	+	75-50
12	—	25-15	—	25-15	—	15-10

+ and — denote the upward and downward mistunings, respectively

of the second sound of an interval varied in the following intervals; 100-75, 75-50, 50-25, 25-15 and 15-10 ct upwards and downwards. The tolerance range resulted from the restricted real possibilities of tuning in the particular sounds of instruments used.

The pause between each pair of tests was 5s. This pause was destined for the answer of the person tested. The pause within each pair of tasks was 1.5s (mostly hardly above 1.5s), while the pause between successive series was 10s.

After listening to each pair of melodies, it was estimated whether the intonation of the last sound in the control melody coincided with the intonation of the last sound in the standard melody. In the case the coinciding intonations were perceived, the answer was "yes", while in the case when a change in the intonation was perceived, the answer was "no". The investigator wrote the assessments in a control card under a number corresponding to a given melody pair estimated (yes as + and no as —). These signs were interpreted as correct or incorrect answers, depending on whether the intonation coincided in a given pair or the detuning took place. Each song on which the tests were drawn had been sung in class before.

b. Sinusoidal tests. A sinusoidal test had the same composition as the coloured tests, consisting of four series corresponding to the same intervals: series I — 1, II — *2m*, III — *2w* and IV — *3m*. Each series contained 12 pairs of isolated intervals given in a quasi-stochastic order, where in 10 pairs the first interval was a standard, while the second was a mistuned one, and in 2 pairs both intervals were not detuned. The particular intervals were elaborated with keeping the same pitch register and the motion direction as in the coloured tests. The detunings of the second tone were 75, 50, 15 and 10 ct upwards and downwards. The duration of the interval tones was 1.00 s, the pause between the intervals in a pair was 1.67 s, while the response time was 1.77 s. The rise and decay times of the signals were 0.05 s.

3. Recording procedure

a. Sinusoidal tests. The tests of sinusoidal tones were programmed using a three — channel analog modulator [5]. The standard and control (variable) intervals were supplied from a sinusoidal tone generator at a grequency stability of the order of 10^{-4} per day. The signal frequency was measured with an electronic counter with an accuracy of 10^{-2} Hz. The durations of the intervals and of the pauses between the intervals were controlled by a unit of logical modules with an accuracy of 1 per cent. The sound material was recorded on a magnetic tape with a Nagra IV-*SJ* tape recorder at a tape shift rate of 0.19 m/s.

b. Coloured tests. In producing pianoforte tests, sounds were detuned by normal tuning of an instrument. A piano-tuner tuned or detuned given sounds to a desired pitch by ear. At the same time, the correctness of detuning was controlled by observing the Lissajous figures on an oscilloscope display. Control measurements showed that after some time the tuner remained in most cases within the predetermined detuning limits.

Electronic control consisted in precise comparison of the frequency of the fundamental tone of a given piano sound with a signal of the same frequency, with an accuracy of 0.1 Hz. The set of the apparatus used is shown in Fig. 2. The piano player played a piece of a melody with a desired detuning, at a fixed tempo and dynamics. The tempo of the melodic pieces was controlled with a metronome in a next-door room. The piano player received the metronome signal by earphones. The variations from 70 to 80 dB in the level of sounds being recorded were tolerated. A large difficulty in test shaping was the undesired detuning of sounds adjacent to the purposefully detuned sound when the latter was being detuned. Therefore, before the final form of the test was set, the tune of both sounds of an interval was controlled additionally and corrected, if necessary.

The procedure of recording tests composed of flute and violin sounds was similar to that of recording the pianoforte tests. The difference consisted in changing the order of recording and control. The musician formed the test material for recordings a number of times, detuning a given sound on the basis of subjective auditory assessment. And only then was the real magnitude of the detuning controlled by objective measurements, and the chosen variant of the

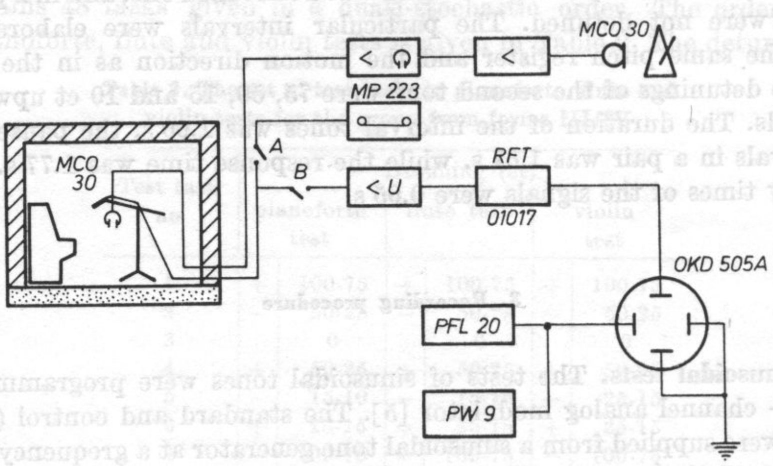

Fig. 2. A block diagram of the apparatus used for the recording and control of the music material for the coloured tests

whole melodic piece, which was assigned to a relevant group of detunings, to be edited further, was recorded. When all the detunings were ready, the whole series was edited. In this way, although the whole recording procedure was very long (particularly, in the case of the flute tests), the editing of a test within one melodic piece was avoided.

c. Control of tests. The experimental material of the violin and flute tests underwent a spot detailed check in terms of the frequency and the amplitude ($F0$ and $A0$) of sounds making up the intervals investigated. This check was based on the intonographic record made with an analogue-digital system [15]. The measurement set consisted of a MERA 30 mini computer (a digital convertor with memory), a DT-105 paper tape punch, and a CT-1001 punched tape reader.

4. Persons examined

On the basis of the results of the previously mentioned experiment performed under natural conditions, three children were chosen from each form in each centre. They represented the "average student" group in terms of musical training, with particular emphasis on the perception of melodic intervals. All the children had normal physiological hearing, with a hearing loss tolerance of up to 30 dB.

There were the following age groups: the first consisted of 36 children from forms I and II (27 girls, 9 boys), including 3 children from the centres *M* (1+2), 20 children from the centres *m* (17+3), and 12 children from the centres *W* (9+3). The second group had 43 children from forms III and IV (28 girls, 15 boys), including 13 from the centres *M* (10+3), 18 from the centres *m* (7+11) and 12 from the centres *W* (11+1). The third group consisted of 63 children from forms V and VI (56 girls, 7 boys), including 22 from the centres *M* (21+1), 18 from the centres *m* (16+2) and 23 from the centres *W* (19+4).

The children selected for participation in the acoustic tests had earlier taken part in music testing in class. They were familiar with the laboratory conditions in the course of checking the audibility threshold curves. In order to prevent surprises in terms of organization, the children were instructed preliminarily about the investigation procedure. All the selected children volunteered for the tests, and were under the care of their music teacher. Four children had to be dropped in the course of the investigations, since they gave totally accidental answers, which was found in the preliminary control of answer repeatability. The total lack of repeatability may have been caused both by the bad perceptibility or the lack of attention.

5. Listenings

In order to avoid additional distortions and disturbances while reproducing tape recordings, caused by the amplification system, each time before the measurements followed, the nonlinear distortions of the power amplifier and the efficiency of the "contour" filter and the anti-noise filter were controlled. The same power level at the output of the amplification system was controlled before each listening.

The listenings took place in a GIG AU-1 audiometric booth, with SN-60 earphones, binaurally. The otter apparatus was installed in the room where the booth was. The connection diagram was the same as in paper [4].

The intensity level of the sound received corresponded approximately to the level on which the sound reached the microphone in the recordings. The student gave answers yes or no through a microphone in the booth, which permitted contact with the person recording the answers. A five-minute intermission was taken after two series. Each student was tested at least three times; with usually one session for each student per day; in the rare cases when the student lived far from Zielona Góra, two sessions were conducted. The duration of listening to each series was about 240 s. Each successive series was preceded with a special announcement.

6. Analysis of the results

The results were tabulated for each group, for the particular intervals individually. As an example, the results obtained for the children group of forms V and VI are shown in Tables 3-5. 75 per cent of the correct answers was taken as the criterion of interval detuning perceptibility. On the basis of the tables, histograms of the correct answers were elaborated in relation to the detuning degree of an interval (Figs. 3-5). The black column represents the percentage of the correct answers for a nondetuned interval.

a. Children group from forms I/II. Pianoforte tests. 36 children were tested. The maximum number of answers for each detuning in the intervals 1, 2*m*, 2*w*, 3*m* was 128 for each melody containing a detuned interval and 256 for a melody with a nondetuned interval.

The distinctly best perceptibility was found for the upward detuned prime interval (88 per cent of correct answers for 25-15 ct upwards), and minor third downwards (above 71 per cent of correct answers for 25-15 downwards). The perceptibility of detunings in the minor second and major second intervals was similar, including for the major second the detunings of 50-25 ct upwards and for the minor second and major second only 75-50 ct downwards*.

b. Children group from forms III/IV. Tests of all kinds. 43 children were tested with pianoforte tests. The maximum number of answers for each detuning in all the intervals was 151 for each melody containing a detuned interval and 302 for each melody containing a nondetuned interval.

The best perceptibility was found for the detuned minor third and prime, where, as in group I/II, the downward detuned minor third was perceived better than the upward one, while the detuned prime was recognized better for the upward case than the downward one. Even the least downward detuned minor third was perceived, i.e. 15-10 ct (81 per cent of correct answers), while the least perceptible prime detuning was 25-15 ct upwards (84 per cent of correct answers). The perceptibility of the detuned minor second and major second was similar and, as in group I/II, the detunings in these intervals were perceived up to the range 75-50 ct. Smaller detunings were not perceived.

33 children were tested with flute tests (27 girls, 6 boys). The maximum number of answers for each melody containing a detuned interval was 121, while for that with a nondetuned interval it was 242.

The best perceptibility of detunings was observed for the prime and major second intervals, where results obtained for the prime were similar to those in the pianoforte test. Both for the major second and the prime the upward detunings were perceived better than the downward ones. The least perceptible

* The test pair containing the mistuned interval 2*m* in the range 50-25 ct was damaged in the investigations.

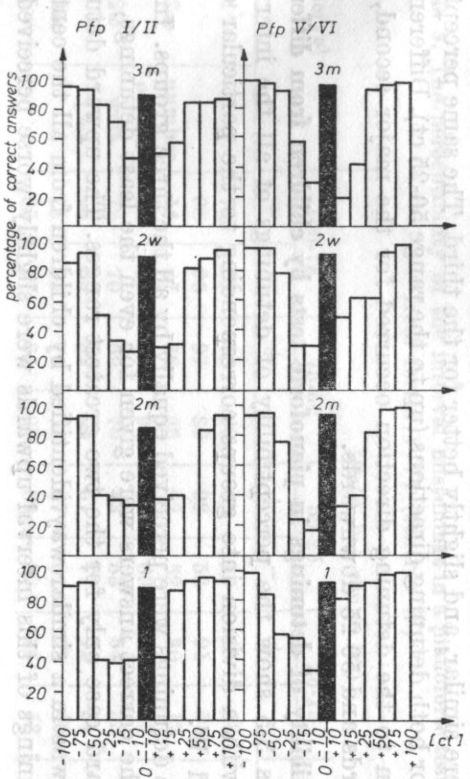

Fig. 3. A histogram of correct ansvers in relation to the mistuning for the student group from forms I/II and V/VI, for pianoforte tests (*Pfp*)

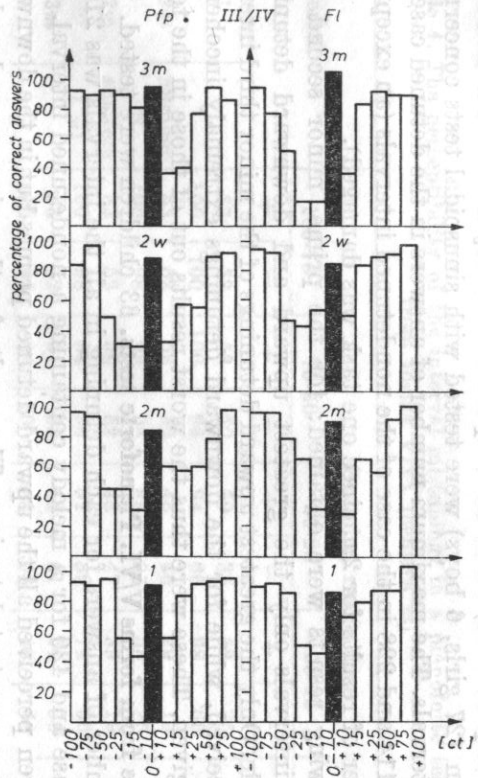

Fig. 4. A histogram of correct answers in relation to the student group in relation to the mistuning for the student group from forms III/IV, for pianoforte (*Pfp*) and flute (*Fl*) tests

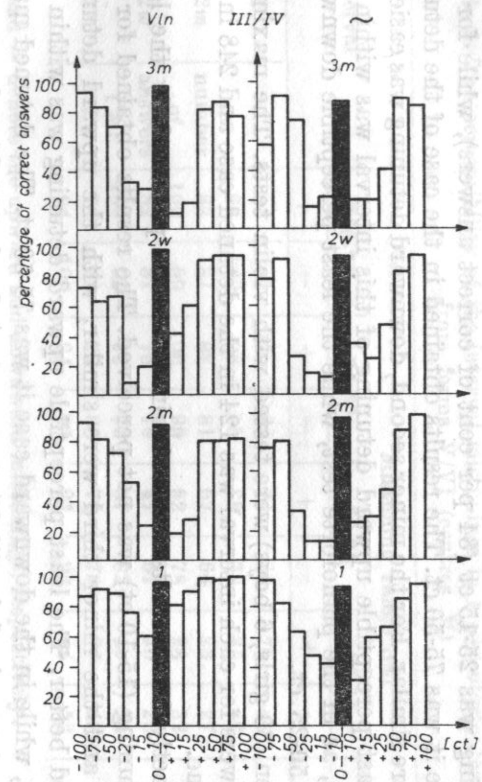

Fig. 5. A histogram of correct answers in relation to the mistuning for the student group from forms III/IV, for violin (*Vln*) and sinusoidal (∼) tests

upward detuning was 25-15 ct (84 per cent of correct answers), while for the downward case it was 75-50 ct. The results obtained in the case of the detuned minor third were similar. For the minor second, downward detuning was easier to detect. The least perceptible upward detuning of this interval was within the limits 75-50 ct, as in the pianoforte test, while the least perceptible downward detuning was 50-25 ct.

36 children (30 girls, 6 boys) were tested with violin tests. The maximum number of answers for each interval was 124 in the detuned case and 248 in the nondetuned one.

The distinctly best results were obtained for the prime. Only the least downward detuning (15-10 ct) was not perceived. The results obtained for the minor second and the minor third were similar, with the upward detuning being perceived better. The least perceptible upward detuning was within the limits 50-25 ct, while in the downward case it was 75-50 ct. The detuned major second was worst perceived, i.e. 50-25 ct upwards and only 100-75 ct downwards.

33 children (27 girls, 6 boys) were tested with sinusoidal tests concerning the isolated intervals. The maximum number of answers in the detuned case for each pair was 114 and 228 in the case of the nondetuned intervals (an exception was the number of results for $2w$, since one task was damaged).

The following results were obtained: for the prime, minor second and major second intervals only the greatest upward and downward detunings were perceptible. Only the greatest upward detunings of the minor third interval were also perceived, while for the downward detunings extremaly incoherent answers were given. These were thus the worst results out of those in the tests.

c. Students from forms V/VI. Pianoforte tests. 63 children were tested. The maximum number of answers for each detuning in all the intervals was 210 in the detuned case and 420 for a melody containing a nondetuned interval.

The children perceived all the upward detuned primes but in the downward case only the two greatest detunings. The results for the minor second and the minor third were similar, and slightly better for the third. The same perceptibility occurred for both detuning directions (up to the range 50-25 ct). Differentiation in relation to the detuning direction occurred for the major second, i.e. 75-50 ct upwards and 50-25 downwards.

d. Perceptibility of detunings in pianoforte tests by children from different centres. Tables 3-5 show the perceptibility of detunings of all the intervals investigated, with a division into groups corresponding to the particular centres *M*, *m* and *W*.

The prime detunings were perceived equally by all the three groups. In the upward case the correct answers were given for even the least detunings, and in the downward case only for the two greatest ranges. The upward detuned minor second was in a similar way identified by children from all the centres, while the detunings of this interval upwards were slightly worse perceived by

Table 3. The perceptibility of the interval mistunings in a pianoforte test for the children from forms V/VI (centres *M*)

Interval		Mistuning range (ct)										
		100-75		75-50		50-25		25-15		15-10		0
		+	–	+	–	+	–	+	–	+	–	
1		81	82	79	68	72	48	70	46	65	31	149
		99	100	96	83	88	58	85	56	79	38	91
2*m*	number	82	81	82	81	67	64	23	27	24	16	156
	of	100	99	100	99	82	78	28	33	29	19	95
2*w*	answers	82	81	76	79	47	67	40	20	29	21	151
	[%]	100	99	93	96	57	82	49	24	35	26	92
3*m*		77	82	77	80	76	76	37	43	18	21	155
		94	100	94	98	93	93	45	52	22	26	94

+ and – denote the upward and downward mistunings, respectively.

Table 4. The perceptibility of the interval mistunings in a pianoforte test for the children from forms V/VI (centres *m*)

Interval		Mistuning range (ct)										
		100-75		75-50		50-25		25-15		15-10		0
		+	–	+	–	+	–	+	–	+	–	
1		53	53	53	50	50	35	52	35	50	20	99
		100	100	100	94	94	66	98	66	94	38	93
2*m*	number	53	52	52	52	45	45	29	13	21	7	103
	of	100	98	98	98	85	85	55	25	40	13	97
2*w*	answers	53	52	50	52	43	47	39	19	36	16	104
	[%]	100	98	94	98	81	89	74	36	68	30	98
3*m*		53	52	51	53	52	51	24	36	11	14	106
		100	98	96	100	98	96	45	68	21	26	100

Table 5. The perceptibility of the interval mistunings in a pianoforte test for the children from forms V/VI (centres *W*)

Interval		Mistuning range (ct)										
		100-75		75-50		50-25		25-15		15-10		0
		+	–	+	–	+	–	+	–	+	–	
1		74	72	73	60	69	40	68	38	56	21	138
		98	96	97	80	92	53	91	51	75	28	92
2*m*	number	74	67	56	69	62	52	30	17	26	16	136
	of ans-	99	89	75	92	83	69	40	23	35	21	91
2*w*	wers	72	70	69	70	43	53	54	23	40	25	133
	[%]	96	93	92	93	57	71	72	31	53	33	89
3*m*		71	73	71	73	67	67	27	40	12	28	136
		95	97	95	97	89	89	36	53	16	37	91

children from the centres *W* (by one detuning group). In the case of the major second and minor third intervals the detunings were perceived best by the children from the W centres. Thus, no generally distinct difference was found between the results of children from the groups *M* and *W*; and the group *m* had the best results.

This, however, cannot be taken as a rule, since in the group from forms I/II the children from the centres *W* perceived the detunings better than the children from the group *m*.

No general relation was thus found to exist between the character of the centre and the perceiving abilities in terms of detunings, although it can be expected that in larger centres with the usually more intense musical life a greater musical training of children occurs, which is significant in the perception of detunings.

7. Conclusions

The following general conclusions can be drawn from the results of the investigations performed on all the student groups in all the tests.

1. The upward detuned interval 1 is best perceptible up to the range 25-15 ct, where in two cases: in a violin test for forms III/IV and in a pianoforte test for forms V/VI, even the least detunings were perceived. The best perceptibility of the detunings of the interval 1 was found for violin tests.

2. In all the tests and age groups the detuning of the interval 3 *m* was perceptible up to the range 50-25 ct, i.e. a detuning less than a quarter tone. An exception was made by the flute and violin tests for forms III/IV with the downward detunings (50 per cent and 69 per cent of correct answers, respectively).

3. The upward detunings of the interval *2w* were worst perceptible.

4. No relation was found to exist between the ability of perceiving the intervals 1,*2m*, *2w* and *3m* in an "average student" and his age or the character of the centre from which he came.

5. A student of average musical ability can perceive the detunings in the melodic intervals below a quarter tone. This fact should be taken into account while programming musical training in school.

6. None of the three sound timbres (pianoforte, violin, flute) dominates unambiguously over other two in terms of the effect on the perceptibility of the detunings of the melodic intervals 1,*2m*, *2w* and *3m*.

7. The detuned intervals composed of sinusoidal tones are less perceptible than those composed of coloured sounds of such instruments as the piano, violin, or flute. It seems, therefore, that the sound timbre plays an essential role in perceiving the detuned melodic intervals. What may also be significant is the context in which the interval occurs (the sinusoidal intervals were presented

in isolation, while the "coloured" intervals were given in the context of a melodic phrase).

8. In the group of the intervals investigated the best perceptibility was found for the upward detuning of 1, and the worst for the downward detuning of *2w*.

9. A tendency for the zone of the interval 1 to expand was found, as a result of the tolerance of the upward detuning of this interval.

10. *2w* shows a tendency to expand its magnitude, as a result of the tolerance of the downward detunings, which agrees with the detuning direction and the motion direction of the interval.

11. In moving from degree VII to degree VIII *2m* shows a tendency to decrease its magnitude, as a result of the higher tolerance of the downward detuning.

12. *3m* shows no tendency to either decrease or increase its magnitude.

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