Influence of Music Education and Interval Size on Grouping of the AB-AB Sequence Sounds

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Abstract

This paper discusses an experiment conducted with two groups of participants, composed of musicians and non-musicians, in order to investigate the impact that the speed of a sound sequence and the interval size which selected sounds are played on the grouping of sounds into perceptual streams. Significant differences were observed between musicians and non-musicians with respect to the threshold sequence speed at which the sequence was split into two streams. In modern psychoacoustic studies, the qualifying criteria for listeners usually include otologically normal hearing (verified by audiometric test) and age. The differences in the results for the two groups suggest that the musical background of the participating listeners may be a vital factor. The criterion of musical education should be taken into account during experiments so that the results obtained are reliable, uniform and free from interpretive errors.

Keywords: perception; music; learning; art and cognition; auditory scene analysis

Introduction

Hearing involves receiving sound stimuli and interpreting them in the brain by an individual, i.e. perception. The perception discussed here is one of the most interesting research aspects pertaining to psychoacoustic experiments. Perception is related to different activities occurring in the human auditory system – sensory processes and cognitive processes. Sensory processes are based on adapting sound waves to nerve stimuli. The above-mentioned processes function in an almost identical manner in all humans (provided that the otological condition of the auditory system is appropriate and this system functions correctly) regardless of age, occupation, musical education, etc. Cognitive processes are related to the past experiences of a given individual and to the processing of sound information reaching the auditory organ in their mind. The differences between people with and without musical education are the result of cognitive processes such as attention, awareness, perception, memory, thinking and reasoning (Nęcka, Orzechowski & Szymura, 2006), which can be acquired through musical education – at the same time affecting experimental results obtained in a group of musicians. The information regarding the possession or lack of musical education is particularly significant when conducting auditory experiments related to the mental processing of sounds as perceptual streams. The way these processes work in the two groups mentioned above may be different, making it quite likely that individuals with and without musical training may perceive the same sequences of sounds in very different ways, which is very significant during the analysis of data and drawing conclusions.

Methods

Experiment used the interval size as the variable. Subjects were played sequences constituting intervals of a minor second, perfect fourth and major seventh. The experiment was based on those described by Miller and Heise (1950), Dowling (1968), Bregman and Campbell (1971), Bregman (1990), and van Noorden (1975, 1977). It investigated the phenomenon of sound grouping into perceptual streams based on the pitch difference between two sounds, depending on the tempo of sequence playback (Auditory Research Laboratory. (n.d.).). The sound pairs were played in different octaves.

The experiment presented repeating sequences comprised of two sounds separated by a minor second, perfect fourth and major seventh. All intervals were in a one-line octave. Sound frequencies were established according to equal-temperament tuning:

– minor second: e1 = 329.630 Hz, f1 = 349.230 Hz,
– perfect fourth: d#1 = 311.130 Hz, g#1 = 415.300 Hz,
– major seventh: c1 = 261.630 Hz, h1 = 493.880 Hz.

The duration of each sound was computer-generated and lasted from 400 ms to 40 ms (Bregman, 1990; Dannenbring & Bregman, 1976a; van Noorden, 1977). In order to avoid crackling in audio replay, the amplitude envelope of each sound was given a linear attack and release of 10 ms (Dannenbring & Bregman, 1976b). The temporal sequence of sounds was regulated and analysed by software on the WPF .NET platform. Time control of sound duration was modelled after the sound material used in the experiment described by Bregman and Campbell (Bregman & Campbell, 1971; Auditory Research Laboratory, n.d.). The duration of sounds gradually decreased over the course of the task, following a hyperbolic function, according to the formula:

$$t = ((-1/(3x+1))+1)*(4/3) \qquad (1)$$

where t signifies the duration of a single sample, and x signifies the time elapsed since the sequence start.

The series of sounds was presented a maximum of 207 times, which gives 414 sounds replayed in a single presentation. Every test (playback of a single interval) was repeated three times. Each repetition of the task was carried out after the answers were given. Each answer was recorded by a computer program and then the arithmetic mean was drawn from them. The program was designed to immediately catch any inconsistencies in the results, for example, if any of

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the subjects inconsistently evaluated the incoming sequences (i.e. each time they indicated a totally different point of splitting the sounds into two streams). No errors were observed in the respondents' answers in the conducted experiment, as the evaluation criteria used by the listeners were stable and recurring.

Listening sessions were held in computer room 120 of the Gdańsk Academy of Fine Arts, and in chamber music hall S2 of the Gdańsk Academy of Music. The listening station comprised the following elements:

– Asus M51VA-AP117 portable computer with Windows 7 Ultimate 64-bit operating system, and the Microsoft programming platform Windows Presentation Foundation (WPF .NET). The application was developed in the Microsoft Visual Studio 2013 programming environment.
– Beyerdynamic DT 770 pro closed headset with 80-ohm impedance.

The volume of the stimuli was determined in a previous pilot study involving three musicians and three non-musicians with no prior experience with auditory experiments. These individuals established a level of audio path amplification that supplied the volume of maximum comfort during the listening experiment. The established loudness level was approximately 70 phons. All audio samples were generated on the WPF .NET software platform with the Microsoft Visual Studio 2013 development environment, using a mono system with a 44.1 kHz sampling rate and a resolution of 16 bits. The response was given by pressing the "space" key on the computer keyboard at the moment when the subjects noticed the segregation of sounds into two perceptual streams.

All analyses and statistical calculations were carried out using IBM SPSS Statistics V23.0 software.

Data on left- or right-handedness were provided by the subjects, who themselves answered the question asked in a digital survey. In this case, the researcher relied on the information received from the participants, as no questionnaires related to the examination of the functional dominance of the left or right hand were used.

The experiment involved 48 subjects, aged 21 to 27, including 24 students or graduates of the Gdańsk Academy of Music and 24 students or graduates of the Gdańsk Academy of Fine Arts. The group of 48 subjects was comprised of 40 women and 8 men. Candidates for the groups were recruited at random.

The study was designed as a series of experimental sessions, all of which involved two groups of subjects: students and young graduates of the Academy of Music, and students and young graduates of the Academy of Fine Arts who were non-musicians. For the purposes of this paper, students of the Gdańsk Academy of Music and young professional musicians are jointly referred to as "musicians", while "non-musicians" are the students of the Academy of Fine Arts, including individuals with some experience in amateur music. Detailed data of participants' education, professional speciality and music experience are presented below.

– Subjects began their education between the ages of 5 and 10, and graduated from primary and secondary music school.
– They continuously practiced playing musical instruments over the last 13–22 years.
– Professional education of three subjects was temporarily interrupted for incidental reasons.
– The subjects did not possess absolute pitch.
– The subjects mostly performed classical music.
– All subjects were right-handed.

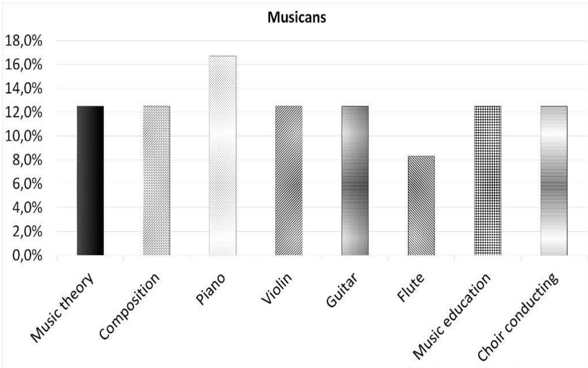

Figure 1: Percentage of subjects among musicians by academic focus or professional specialty.

– Five subjects had attended a music centre, primary music school, or private lessons in singing or instrumental music. Those individuals received a few years of music education, and some of them were involved in amateur music performance.
– Other subjects received no instrumental or singing instruction, nor performed music as amateurs.
– The majority of non-musicians listened to general popular music.
– All were right-handed.

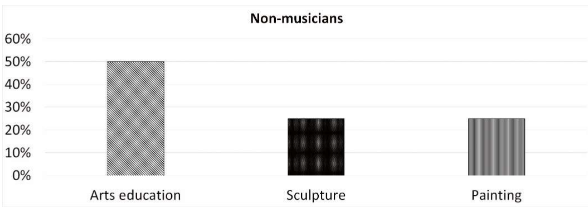

Figure 2: Percentages of non-musicians by academic focus or professional specialty.

The study was conducted in listening sessions separate for each participant. The subjects were instructed to indicate the moment that they heard the sounds separate in two perceptual streams. It was thoroughly explained to all the study participants what perceptual streaming is, how it occurs, and in what way sounds are being integrated into a single stream or segregated into two streams. The instructions given and the exercise material must be prepared by the researcher with precision, since answers regarding the phenomenon of integration or segregation of sounds into perceptual streams may be given incorrectly by the listeners, through a subjective evaluation of the subjects' experience. A slight change in the emphasis of a question or command may result in a different attitude of the subject, making the perceptor concentrate on other elements of the auditory image or analyze it in a different way, since the respondents may understand the same task differently. To ensure the replication of the results, it is crucial to give precise instructions combined with prior preparation of the subjects for the experiments, and proper transfer of the experiment contents transmitted by the device in order to make the subjects understand them. At the beginning of the session, a demonstration series was played, taken from the work by Bregman (Bregman & Campbell, 1971; Auditory Research Laboratory, n.d.), in order to familiarise the listener with the phenomenon of perceptual fission and to explain the experimental task.

Results

Table 1 presents group results of the experiment – mean sample duration at each group's indication of perceptual stream fission, as well as standard deviation and standard error of each value set. Values shown in Table 1 are displayed in graphical form in Figure 3.

Table 1: Group results of experiment – mean sample durations in milliseconds, at which each listener group indicated sounds separating into two perceptual streams, as well as standard deviation and standard error of each value set. Results are divided by interval: minor second, perfect fourth, and major seventh.

	Group	*N*	Mean	Standard deviation	Mean standard error
Minor second	Musicians	24	116.79	31.656	6.462
	Non-musicians	24	160.29	51.684	10.550
Perfect fourth	Musicians	24	96.46	28.304	5.778
	Non-musicians	24	171.04	53.971	11.017
Major seventh	Musicians	24	81.46	28.338	5.784
	Non-musicians	24	170.13	55.270	11.282

Figure 3 presents responses given by musicians and non-musicians as to the duration of sample sounds (threshold) at which they experience fission of perceptual sound streams. The graph shows mean values and standard deviations of the sets of 24 responses in the musician group and non-musician group, divided by intervals: minor second, perfect fourth, and major seventh.

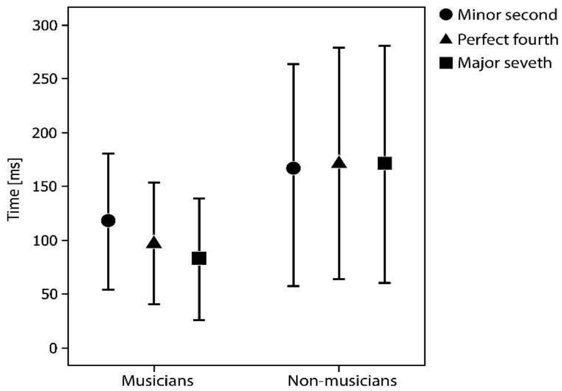

Figure 3: Duration of samples at which sounds separated by a minor second, perfect fourth, and major seventh fissioned into two perceptual streams.

To investigate whether differences in mean results between the groups of musicians and non-musicians carry statistical significance, a Student's *t*-test for independent samples was performed. The calculated *t* values and the associated *p* likelihood values are shown in Table 2. *p* values, shown in the rightmost column, are ($p < 0.001$), which is grounds for rejecting the null hypothesis that the average results in the two groups are not statistically different.

Table 2: Results of Student's t-test for independent variables.

	t-test for equality of means		
	t	*df*	Significance (two-tailed)
Minor second	-3.516	23	$p < 0.001$
Perfect fourth	-5.996	23	$p < 0.000$
Major seventh	-6.994	23	$p < 0.000$

Figures 4–6 show histograms of subject responses in tests regarding auditory stream fission in two perceptual streams. The set of 24 responses in the group of musicians and non-musicians was segregated in discrete time intervals. The x-axis shows the number of subjects whose responses fell in a particular interval. Subsequent figures show graphs relating to sequences played in the minor second, perfect fourth, and major seventh intervals.

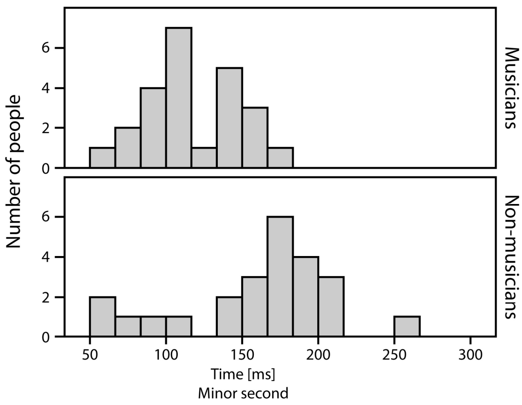

Figure 4: Number of subjects – musicians and non-musicians whose responses fell in particular time intervals plotted on the x-axis. Results for sound sequences played in the interval of a minor second.

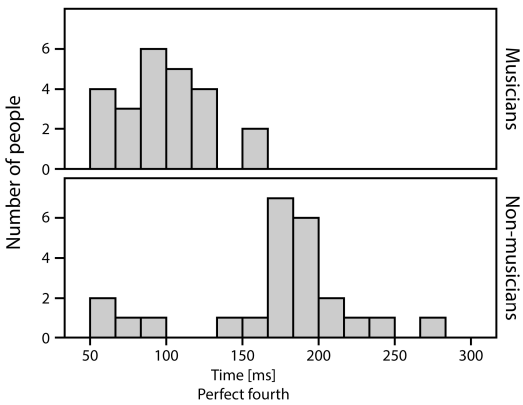

Figure 5: Number of subjects – musicians and non-musicians whose responses fell in particular time intervals plotted on the x-axis. Results for sound sequences played in the interval of a perfect fourth.

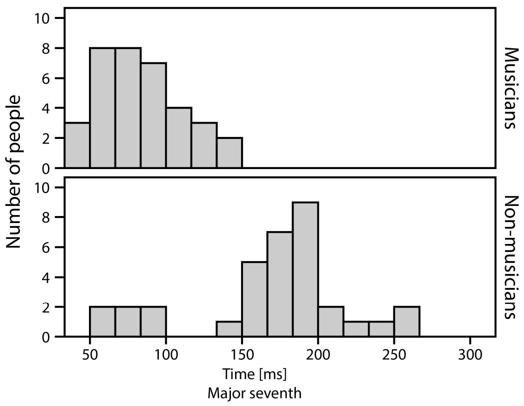

Figure 6: Number of subjects – musicians and non-musicians whose responses fell in particular time intervals plotted on the x-axis. Results for sound sequences played in the interval of a major seventh.

Table 3 shows values of the Pearson correlation coefficient describing the level of linear correlation between variables in experiment, in the group of musicians, including years of continuous practice, age when instrument lessons began, sample duration results in the minor second, perfect fourth and major seventh.

Data presented in Table 3 show that there is a statistically negative correlation between the number of years of continuous music practice and the duration of sound at which sequences in the intervals of the minor second, perfect fourth and major seventh fissioned into two perceptual streams. There is also a positive statistical correlation between the listener age at which instrumental instruction was received and the above variables (sound duration in intervals of a minor second, perfect fourth, and major seventh).

Table 3: Values of the Pearson correlation coefficient between variables in the group of musicians, and their statistical significance.

		Years of continuous practice	Age at first instrumental lessons	Minor second	Perfect fourth	Major seventh
Years of continuous practice	Pearson correlation coefficient	1	-0.839	-0.535	-0.637	-0.610
	Significance (two-tailed)		0.000	0.007	0.001	0.002
	N	24	24	24	24	24
Age at first instrumental lessons	Pearson correlation coefficient	-0.839	1	0.655	0.736	0.755
	Significance (two-tailed)	0.000		0.001	0.000	0.000
	N	24	24	24	24	24
Minor second	Pearson correlation coefficient	-0.535	0.655	1	0.909	0.842
	Significance (two-tailed)	0.007	0.001		0.000	0.000
	N	24	24	24	24	24
Perfect fourth	Pearson correlation coefficient	-0.637	0.736	0.909	1	0.970
	Significance (two-tailed)	0.001	0.000	0.000		0.000
	N	24	24	24	24	24

Major seventh	Pearson correlation coefficient	-0.610	0.755	0.842	0.970	1
	Significance (two-tailed)	0.002	0.000	0.000	0.000	
	N	24	24	24	24	24

Figure 7 presents scatter plots of the correlations observed in experiment in the group of musicians among the following variables: age, years of continuous practice, age at first instrumental lessons, minor second, perfect fourth and major seventh.

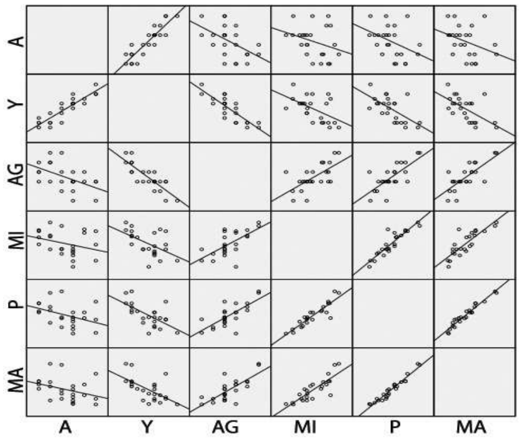

Figure 7: Scatter plots of correlations observed in the group of musicians [signs: A – age, Y – years of continuous practice, AG – age at first instrumental lessons, MI – minor second, P – perfect fourth, MA – major seventh].

Discussion of Results

Experiment was established that the fission of a sequence of melodic intervals in two perceptual streams, i.e. the trill threshold (in the case of a minor second), or tremolando threshold (in the cases of perfect fourth and major seventh), occurs in musicians at a faster tempo (shorter sound duration) than in non-musicians. The second clear distinction between the results in the two groups of listeners was that in musicians, the threshold sound duration diminished as the size of the interval was increased. The trill threshold and the tremolando threshold, calculated as the mean response of musicians, reached from 117 ms in the case of the minor second to 81 ms for the major seventh (Figure 3). In the group of non-musicians, sound duration at the trill and tremolando thresholds was similar for all three intervals and reached from 160 to 171 ms. In experiment, results of non-musicians were characterised by a much greater dispersion than those of musicians.

The fact of perceptual stream segregation occurring at a much faster tempo for musicians than non-musicians is yet another observation confirming that cognitive abilities regarding pitch perception which are acquired during music education and practice, enable musicians to maintain their focus on the pitch changes for a longer time, while the trill or tremolando accelerates.

A statistically significant correlation was observed between the age at which the subject began their music education and the time threshold of perceptual stream fission. This correlation is in line with reports that cognitive processes concerning pitch perception are especially stimulated during music education in childhood (Deutsch, Henthorn, Marvin & Xu, 2006).

In the group of musicians, two factors are evident in their influence on the time of perceptual fission: the tempo of the sequence, and the pitch interval between the sounds. Increasing the interval causes musicians to more easily perceive the changes in pitch, and a faster tempo is needed to trigger the perceptual stream fission.

In the group of non-musicians, changing the size of the interval did not influence the trill or tremolando threshold. The probable cause of this is the general lesser sensitivity of non-musicians to pitch differences and their lack of skill in recognising intervals. The higher sensitivity of musicians to changes in pitch is mostly due to an earlier start in music education and instrumental instruction. In non-musicians, an interval was only perceived as a change in pitch and had no reference to categories of intervals preserved in memory. In musicians, change in the size of the interval was perceived as a change in pitch difference, but also as a qualitative difference, since a musician has the ability to recognise the interval and interprets the pitch difference as one of the categories which constitute the set of musical intervals within the octave.

Because of the differences in sound sequences used in the experiments and those described by various authors, it is not possible to directly compare the present data with that published in the literature.

Conclusion

Routine audiometric tests, conducted while recruiting subjects participating in psychoacoustic tests to check whether the respondents' hearing is otologically normal, are insufficient for this type of research, as they should be extended to include eligibility criteria regarding musical education. The fact that musical education and practice may affect cognitive processes in sound perception should be taken into account when recruiting listeners for psychoacoustic studies, because often identical psychoacoustic experiments repeated on different groups of subjects show that they respond quite differently (Miller & Heise, 1950; Shonle & Horan, 1976). In many cases, musical education can be a factor considerably influencing the outcome of an experiment, which should be recorded as important information, as this fact is not taken into account at all when researchers plan psychoacoustic experiments.

The results of psychoacoustic experiments clearly demonstrate that many years of musical education bring substantial benefits, which can be used by musically educated people, unconsciously, throughout their lives in tasks not only strictly related to music. Broadly understood analysis and processing of sounds in the mind, reaching a person from the external environment, indicates that in the case of musicians there is a different type of interpretation of the sounds incoming to the listener. Musicians can group and isolate sounds differently, paying attention to their different characteristics as compared to non-musicians. Thus music education, when practiced universally, can produce very interesting results when used outside of music, during everyday contact with sounds (Jacobson, Cuddy & Kilgour, 2003).

In the experiment conducted, the same sound grouping phenomena in terms of quality were observed in musicians and non-musicians. When the sounds were shortened and a certain limit (threshold) of the playback speed was exceeded, the AB-AB sequence was split into two perceptual streams, consisting of a higher (A) and a lower (B) sound.

With the qualitative similarity of the phenomena investigated, significant differences occurred between the groups of musicians and non-musicians as to the threshold value of the rate at which the sequence was split into two streams. In the group of musicians, this threshold occurred at a faster speed of playing the sequence than in the non-musicians.

In most sequences presented to listeners for evaluation in these experiments, the speed of sound reproduction at which the sequence split into two streams was about twice as high in the musician group as in the non-musician group.

The fact that the range of speed at which a sequence of sounds of different pitch is perceived as a single stream is wider in musicians than in non-musicians and includes faster speeds indicates that musicians are able to maintain their attention on faster pitch changes in a sequence than non-musicians. The existence of such a difference is an expected observation, since musicians have extensive analytical pitch listening skills developed as a result of practice in playing instruments and the exercises they participate in ear training classes during their education in music schools and music studies. Apart from the speed at which the sequence was played, another variable in the experiments was the interval size between the sounds. Adjustment of these variables significantly affected the results obtained in the group of musicians, while it had no significant effect on the responses provided by non-musicians. When the sequence was played at high speed, the effect of interval size on the threshold for perceiving trill and tremolando was visible. Increasing the interval makes it easier for musicians to retain the perception of changes in pitch, so that the impression that two notes form a common sequence is maintained.

It should be emphasised that the differences between the results obtained in the group of musicians and non-musicians were in most cases significant and showed a high level of statistical significance, which is reflected in the analyses presented in the description of the results in the individual chapters, as well as in the summary presented in the appendix.

The fact that individual results in the groups of musicians and non-musicians were significantly spread in all experiments is very important in the interpretation of the results obtained, with the spread being greater in the non-musicians than in the musicians. In analysing the results of the experiments, it is important to remember that the research referred to phenomena related to cognitive processes, which greatly depend on a given person's experience in sound perception, as well as on many other personal characteristics. Reports published by various authors reveal that the grouping of sounds into streams is determined, among other things, by the functional symmetry of the motor and sensory organs and the lateral dominance (laterality) of these organs (Chambers, Mattingley & Moss, 2002; Deutsch, 1974a, 1974b, 1975a, 1975b, 1980a, 1980b, 1983a, 1983b, 1987, 2004a, 2004b; Efron, Koss & Yund, 1983; Gordon, 1980; Hutchison, Hubbard, Hubbard & Rypma, 2017; Mehta, Jacoby, Yasin, Oxenham & Shamma, 2017; Oehler & Reuter, 2013).

The results may also be of practical importance for musicians, as they broaden their knowledge of the principles of sound perception occurring in situations relevant to technical issues faced by composers of electroacoustic music in their work on the realization of works and by sound directors.

The conducted research also yields a conclusion relating to the recruitment of listeners participating in experiments on psychoacoustic aspects. If the experiments do not address hearing pathology, the eligibility criteria for listeners in the experimental group usually include the fact that the person has otologically normal hearing, which is checked by routine audiometric testing, and, in some cases, the age of the listener. Contemporary psychoacoustic research is paying increasing attention to issues relating to cognitive processes in sound perception. The results obtained in this study show that in this type of research, it may be very important to consider whether the listeners participating in the research have a musical background.

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