The Role of the Amplitude Decay for the Evaluation of Major and Minor Chords in Amateur Listeners and Professionals

Skorik S.O. [a*] *& Almayev N.A.* [b]

[a]*Institute of Psychology, Russian Academy of Sciences, Moscow, Russia, ORCID iD:* 0000-0003-1702-0721
[b]*Institute of Psychology, Russian Academy of Sciences, Moscow, Russia, ORCID iD:* 0000-0003-1433-2869

Abstract: Many studies within the framework of the Western music psychology demonstrate the ability of non-musicians to recognize major and minor musical scales. The aim of this work is to study the ability of subjects to evaluate the emotional valence of major and minor triad chords based solely on their tonal characteristics, as well as to find out what differentiates musicians from non-musicians in recognizing emotions caused by isolated musical chords, both generated and real. The study involved 103 subjects. The stimuli consist of three groups of generated major and minor triad chords and one group played on the piano. For the evaluation of stimuli, two sets of unipolar and bipolar scales formed on the basis of the previous free descriptions are used. The specific attenuation pattern of the signal's intensity (i.e., sustain, decay and release segments of the amplitude envelope) is the decisive factor for major and minor chords perception. Without it, amateurs are unable to estimate the differences between the chords while its presence almost equates amateur listeners and professionals in their evaluations. Although, the latter are able to distinguish the chords based solely on the tonal structure, the presence of the amplitude decay influence their perception by either enriching it more than two times or considerably impoverishing it, depending on the familiarity of the attenuation pattern.
Keywords: Music Perception, Emotional Valence, Chords, Tonal Structure, Amplitude Envelope

1. Introduction

The contemporary understanding of the semantic space of music in cognitive musicology and music psychology may be summarized as consisting of 3 dimensions: "Active - Passive" associated with temporal characteristics; "Happy - Sad" associated with tonal characteristics, particularly with minority and majority; and "Tension - Relaxation" associated with the systemic interaction between musical composition characteristics and a generalized evaluation of music experience (Reybrouck et al., p 5, 2018). The major and minor musical scales, important for the evaluation of emotional valence, became the basis of the Western musical system during the Baroque epoch, and up to this day most of the popular music is created basing on these two musical scales. They have been studied for more than a hundred years in music psychology, but the psychological mechanisms of perception and emotional evaluation of these two sound combinations are not yet completely clear, and have no single accepted explanation (Bowling, 2013).

The interest of scientists in this topic is explained by the ability of significantly

**Corresponding author: Skorik S.O. E-mail: stanskorik@mail.ru*
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different groups of listeners to associate the major and minor musical scales with different poles of emotional valence, as it was shown in many studies (see Parncutt, 2014). This result was obtained on the samples of listeners without musical background (Bakker & Martin, 2015), musicians (Kuusi, 2015), children (Thompson & Opfer, 2014), adults with amusia (Gosselin et al., 2015), elderly people (Bones & Plack, 2015), and representatives of non-Western musical culture (Okhova & Poudeh, 2015, Virtala, Tervaniemi, 2017; Fang et al., 2017).

Generally, whole compositions or their fragments are used in music psychology as the stimuli for evaluation of emotional valence. In this case the tonal component of a stimulus interacts with its tempo, rhythm, manner of playing and other variables – they all are blended in the evaluation of a musical composition or melody.

The approach that is based on the estimation of whole compositions revealed stability of such estimations but it makes little headway towards the understanding of this phenomenon's mechanisms. Indeed, in the case of the perception of a whole musical composition, the evaluation of music as "happy" or "sad" may take place due to various factors: the context and background of perception, the structure of the composition, the style of performance, tempo characteristics (Almayev & Skorik, 2015), sound intensity characteristics (subjective loudness), lyrics, etc.

Listeners can evaluate the valence of music emotions not only in the case of a whole composition or its segments but also in the case of an isolated chord or pitch. In the case of the evaluation of a separate chord, the temporal component is minimized, but the tonal component remains in the form of pitches' interrelation to each other. The approach that is based on the evaluation of isolated characteristics allows experimental control of any isolated factor and thus answers the question: what makes it possible for subjects to differentiate basic emotions at each level of consideration — tonal, temporal and etc.?

The study of isolated major and minor chords' perception can provide information about the psychological and psychophysiological mechanisms of tonal perception (Lahdelma & Eerola, 2016; Skorik et al., 2018).

In addition to isolated musical sounds, it looks appropriate to use digitally generated stimuli (Kunavin & Sokolova, 2014; Almayev & Skorik, 2016; Skorik & Almayev, 2018). In this case the researcher can control almost every characteristic of an acoustic event independently, from the specific performing style to music instrument's timbre to sound-producing characteristics, etc.

The most common explanation for the polarity of evaluation as major and minor is the consonance and dissonance concept wherein the listener perceives certain combinations of pitches as annoying, and others as calming due to the cultural conditioning. If the psychological mechanism for evaluating the valence of emotions is based on an evaluation of frequencies of pitches and their ratios, it's expected that generated major and minor chords will convey the valence of emotions of chords as well as the "natural" ones (produced by professional performers) do this. If tonal characteristics are not sufficient, then there are other mechanisms for emotional response which cannot be reduced to the frequencies of sound components.

Of all the available arts, music is the best in directly conveying the basic emotional component (Argstatter, 2016). How can listeners judge musical sounds as happy or sad? At what other characteristics of acoustic events (beyond the tonal) is their perception focused? The study of the emotional valence of music estimation mechanisms is relevant not only in the context of the music perception theory but also in the broader context of non-verbal (or "non-lexical," to put it more exactly) communication components –

that is how information is transmitted without the usage of linguistic signs. Can similar mechanisms work in the case of non-verbal communication, i.e., how do pre-lexical, prosodic phenomena transmit emotions?

The general hypothesis of the study: the mechanisms for the evaluation of the emotional valence of musical sounds are different for musicians and non-musicians. We also suggest that the attenuation of chords' intensity (i.e., a specific profile of decay, sustain and release segments of the amplitude envelope) is an important condition for the evaluation of emotional valence.

The present studies were conducted from 2015 to 2018 for the first time on the Russian sample and their preliminary results were announced in several conference reports (Almayev & Skorik, 2016; Almayev et al., 2017; Skorik et al., 2018); the paper that is presented below is based on the most complete and verified data.

(A) THE FIRST STUDY

This study consisted of two parts: preliminary and main. The goal of the preliminary part was to work out, on the basis of content analyses, a set of subjective scales that fits specific stimuli best of all. In the main part of the study, other subjects evaluated the stimuli based on the set of scales developed in the preliminary part.

A 2. Data and Methods

A 2.1. Subjects

At the preliminary stage of the first study, 20 people without musical education or experience playing musical instruments were involved (50% males and 50% females; the average age was 28.6 ±5.24 years) .

A 2.2. Method

Natural scale major and minor triad chords served as the base for the stimuli material. Using CoolEdit Pro 2.0 audio editor, the sinusoidal rectangular triad chords (see Fig. 1 and Fig. 2) were generated without attenuation from pitches A (A5 - 880 Hz), B (B5 - 987.77 Hz) of the second octave and C (C6 - 1046.5 Hz), D (D6 - 1174.7 Hz) of the third octave. The duration of each sound was 3 seconds. The volume was equaled taking into account the equal-loudness contour and sound level meter, and was about 70 dB.

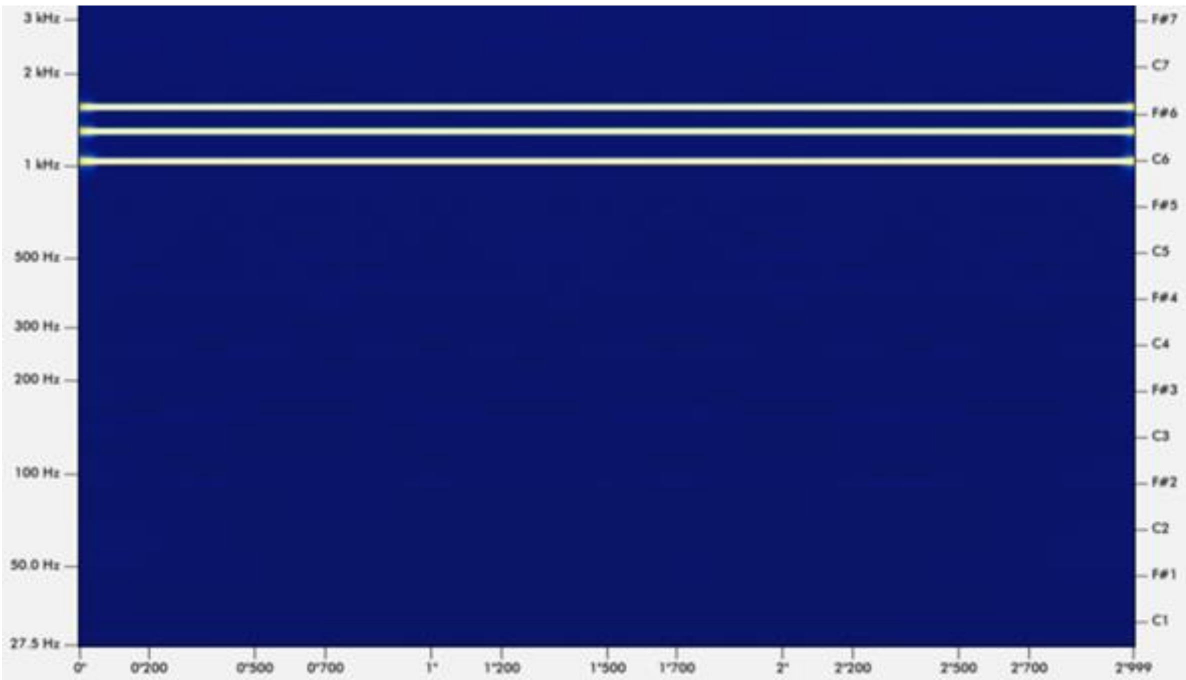


Figure 1. The spectral view of the generated major chord without attenuation from the note C of the third octave consisting of three pitches: the tonic C (C6 - 1046.5 Hz), the major third E (E6 - 1318.5 Hz) and the G (Sol) quint (G6 - 1568 Hz).

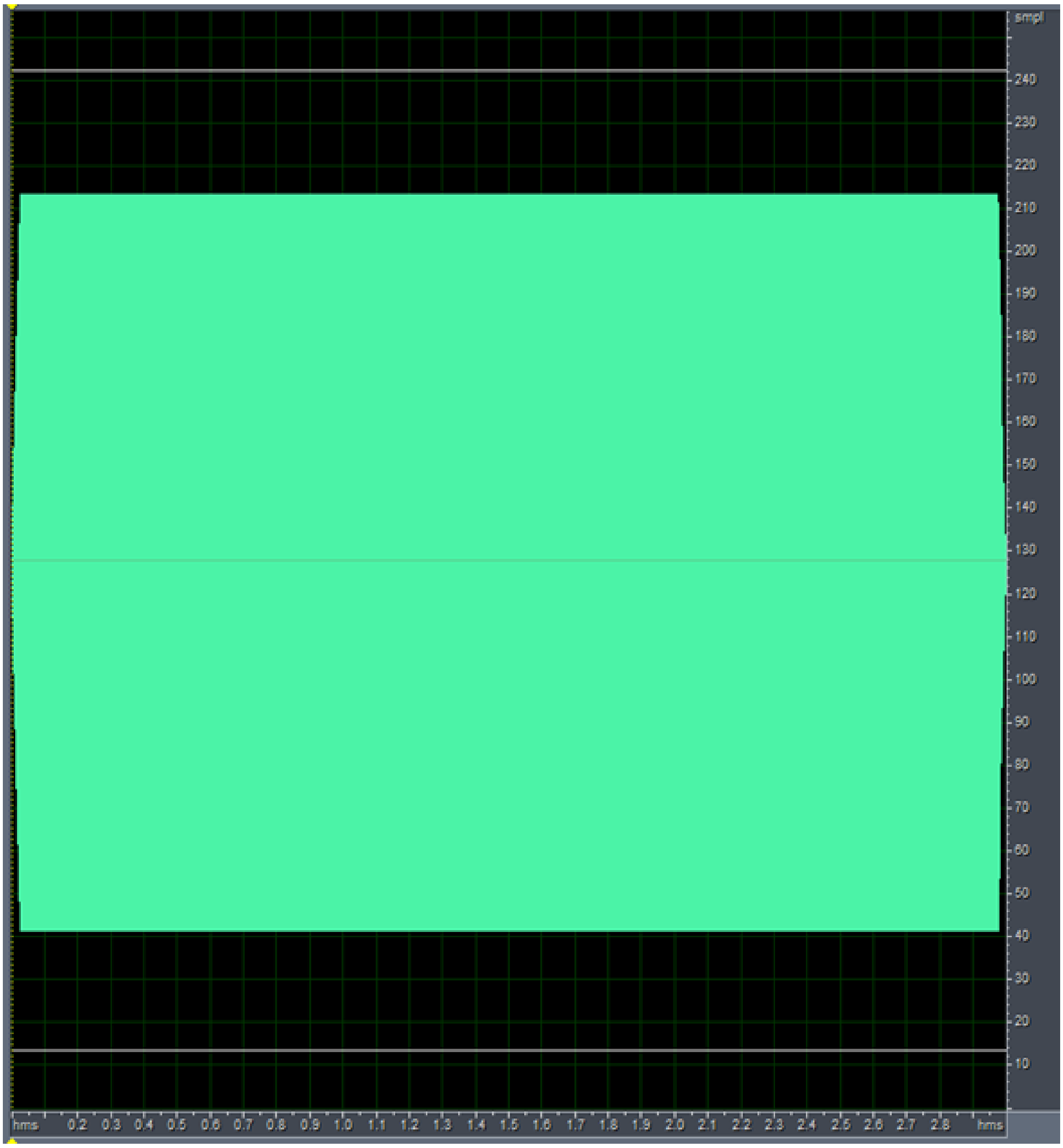


Figure 2. The amplitude view of the generated major chord without attenuation from the note C of the third octave. The first and last 30 *ms* were smoothly muted to avoid "clicks" when the stimuli were turned on and off.

A 2.3. Procedure

The study was conducted in a soundproof room. The subjects were placed in a chair in front of loudspeaker that was reproducing experimental stimuli. The distance from the loudspeaker to the chair was 1.5 m. Triad chords were presented in a randomized experimental design sequence.

In the first part of the study subjects were presented with 8 generated stimuli (4 major and 4 minor, created from 4 tonic pitches) and then with all of their pairs (a total of 32 pairs). The subjects orally evaluated the presented sounds in a free form. A similar assessment procedure was used in the studies of B. Willimek and D. Willimek (2017). Communications proceeded via microphones and were recorded. The following instruction was read out loud:

Instruction. In this study you will listen to sounds and evaluate them. After you have listened to the sound, answer the following questions out loud:

- *What associations did the sound cause?*
- *What emotions and feelings did the sound cause?*
- *What corporeal sensations did you have while listening to the sound?*
- *After answering the questions out loud, say "next sound" out loud.*
- *A total of 8 sounds will be presented to you. Then you will hear their pairs.*

Based on the content analysis of the most frequent subjects' responses, a semantic differential (Likert-type scales) was created consisting of 23 bipolar scales (see Table 1).

Table 1. Scales for subjective evaluation in the first study.

№	Semantic differential scales	
1	Low sound	High sound
2	Unpleasant	Pleasant
3	Ringing	Smooth
4	Relaxation	Tension
5	Indifference	Desire to do something
6	The sound moves away from me	The sound moves to me
7	The sound turns left	The sound turns right
8	Slow	Fast
9	Light	Heavy
10	Close	Far away
11	Dark	Light
12	Younger	Older
13	Quiet	Loud
14	Narrow	Wide
15	Calm	Anxious
16	Passive	Active
17	Sad	Happy
18	Nothing will happen	Something will happen
19	Cold	Warm
20	Negative	Positive
21	Female	Male
22	Boredom	Interest

Regarding the nature of the stimuli more than 90% of associations were with old / cheap / toy/ 8-bit synthesizers / PC-games / gamepads.

The main part of the study was attended by 30 subjects (50% are men, 50% are women; average age is 27.6 years; SD is 5.35) without musical education and experience of playing musical instruments, who evaluated triad chords by using a previously created semantic differential (Likert-type scale). Pairs of stimuli were not presented in the main part of the first study.

In the main part of the study subjects evaluated 8 triad chords in randomized experimental design sequences, presented in a soundproof room with the following.

Instruction: In this study you will evaluate the sounds. After you listen to the sound, evaluate it using the properties that are written on a list in front of you. Each pair of properties describes a feature, the value of which can be determined on a 7-point scale (from -3 to +3). Circle the number which, in your opinion, most accurately characterizes the expression of the proposed feature. After completing the questionnaire, say “next sound” out loud. In total 8 sounds will be presented to you.

After reading the instructions the experimenter left for the next room and began administering the stimuli. During the study, the subjects filled in 8 forms of semantic differential, corresponding to the total number of sounds. The experiment with one subject took from 20 to 40 minutes depending on the speed of filling out the forms.

A 3. Results

A Wilcoxon T-test reveals differences between estimations of minor and major triad chords within the three scales (see Table 2).

Table 2. The values of Wilcoxon T-test for three scales at which significant differences were identified for major and minor chords evaluations.

Scale	Valid N	T	Z	p-value
Boredom / Interest	85	1257.5	2.497605	0.012504
Narrow / Wide	87	1424.5	2.071755	0.038289
Passive / Active	89	1277.5	2.966203	0.003015

In the scales where differences were revealed, major triad chords were evaluated by subjects as more “narrow”, “passive”, and “boring”, while minor triad chords as “wide”, “active”, and “interesting”.

The stimuli from the preliminary study were also presented to three participants who could be described as semiprofessionals: one female aged 22, education – musical college, performs regularly in an orchestra (clarinet), and two males aged 50, one pianist with a conservatory level education but performing irregularly, and one professor of aesthetics with an amateur level of performance (bass-guitar). The main question to them was to identify the nature of presented sounds. The female participant succeeded in this task at about tenth attempt and consequently named the chords. Both of the men identified the nature of the stimuli implicitly by saying that some pairs of them could form harmonies, nevertheless, neither of them, despite their superior level of education in the field, could name the chords explicitly, instead calling them “some synthesized sounds”.

(B) THE SECOND STUDY

B 2.1. Subjects

In order to elaborate the new set of subjective scales, the first group of subjects consisting of 10 people (among them 40% are men; average age is 28.1± 5.24 years) were involved, who evaluated four groups of stimuli (32 sounds) by using the method of free description. The subjects had no musical education or skills in playing musical instruments, except for two subjects, who studied at music schools for 3 years.

The sample of the main part of the second study is 43 subjects. They are divided into two groups:

29 non musicians (51.72% male, 28.28% female; mean age is 26.7 years; SD is 5.8 years) without any musical education or skills in playing on musical instruments;

14 professional musicians (57.1% male, 42.9% female; average age is 28.2 years; SD is 8.29 years); all subjects in the second group studied music, 8 of them received higher levels of musical education, 2 subjects graduated from music schools, 4 subjects studied music on their own and with the help of a tutor. Of the 8 subjects who had higher levels of music education, four subjects graduated from an entertainment-jazz faculty and 4 subjects graduated from a faculty of classical music. The criterion of professionalism was earning at least half of their income by the means of activities connected to performance, editing and/or composing music; thus, the regularity of respected activities was emphasized.

The subjects from the first group participated in an elaboration of the new set of subjective scales, while the second group was engaged only in the evaluation of the sounds according to the previously created semantic differential.

B 2.2. Method

Four groups of sounds were created (see Figure 4 and Figure 5):

(1) The first group (taken from the first study) included 4 major and 4 minor triad chords from the tonic pitches of the second and third octaves, generated without intensity's attenuation (A5 – A; H5 – B; C6 – C; D6 – D). The sound was based on generated sine waves.

(2) The second group was 4 major and 4 minor triad chords generated with linear attenuation from the tonic pitches of the second and third octaves (A5 – A; H5 – B; C6 – C; D6 – D). The sound was based on generated sine waves. In this group of sounds the attenuation was linear, decreasing evenly from the beginning of the sound to the end.

(3) The third group consisted of 4 major and 4 minor MIDI triad chords generated with attenuation from the tonic pitches of the second and third octaves (A5 – A; H5 – B; C6 – C; D6 – D). The sound was based on the *Electric Piano timbre* from the MIDI sounds bank. The amplitude envelope of these stimuli is characterized by a pronounced attenuation to 100-150 msec, and then by the one closer to the linear attenuation until the end of the stimulus.

(4) The fourth group was 4 major and 4 minor triad chords from the tonic pitches of the second and third octaves (A5 – A; H5 – B; C6 – C; D6 – D), taken from the professional Yamaha sound bank, corresponding to the natural sounds caused by pressing keys on a concert piano. The amplitude envelope of the sound in this group of stimuli is a type of inverse or inverse power dependence with a sharp attenuation of intensity within the first 150-200 msec, and then - with the long gentle slope until the end of the stimulus.

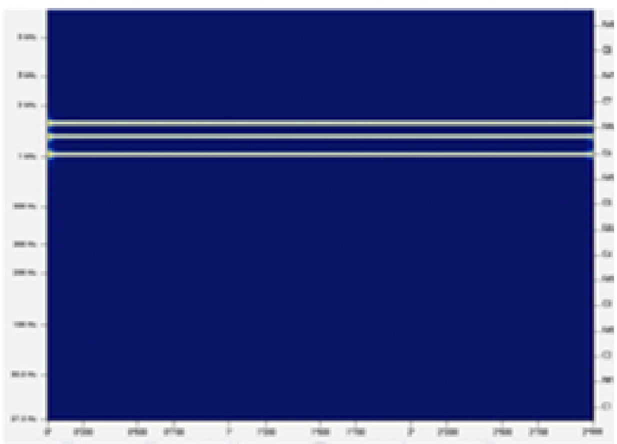
32 chords were presented to subjects in the first part of study. The following instruction was read out loud in advance:

In this study you will listen to sounds and evaluate them. After you listen to the sound, answer the following questions out loud:

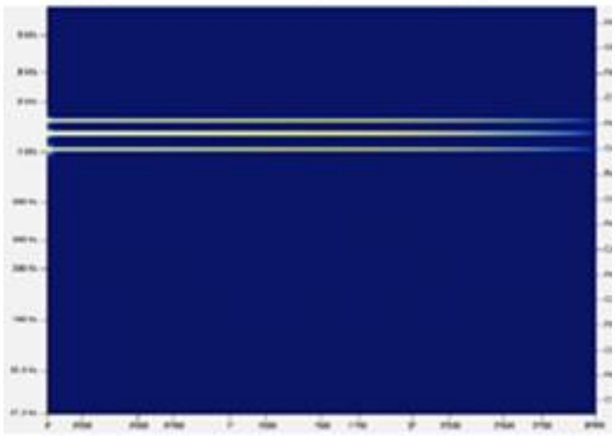
- *What associations did the sound cause?*
- *What emotions and feelings did the sound cause?*
- *What corporeal sensations did you have while listening to the sound?*

After answering the questions out loud, say "next sound" out loud. In total you will be presented with 32 sounds.

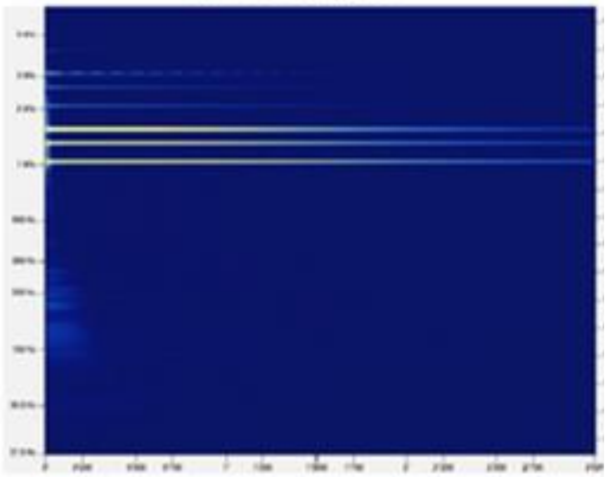
For the main part of the second study, an extended set of subjective scales was elaborated, on the basis of the one from the first study. Content analyses of the descriptions of new groups of sounds were repeatedly conducted, on the basis of the most frequently encountered definitions. In addition to content analysis, descriptions of major and minor keys from musicology were adopted (Kolchinsky et al., 2017). As a result, a semantic differential was developed consisting of 35 scales, including 29 unipolar scales and 6 bipolar ones (see Table 3).



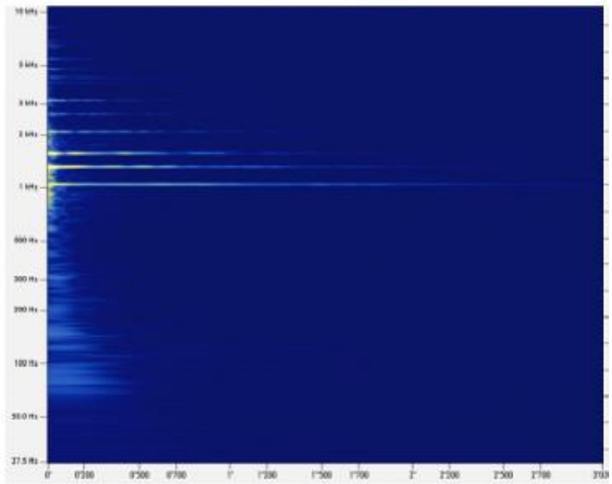
generated sounds



generated sounds with decay



MIDI sounds



real piano sounds

Figure 4. The spectral view of 4 groups of major chords from the note C of the second octave, consisting of three pitches: tonic C (C6 - 1046.5 Hz), major third E (E6 - 1318.5 Hz) and the fifth G (G6 - 1568 Hz). Upper left –no attenuation, upper right – linear attenuation, lower left – midi type, low eight – real type.

The study was conducted in the soundproof room. The following printed *instruction* was given to the subjects:

In this study, you will be presented with sounds. After listening to each sound, evaluate the strength of properties that are written on the sheet in front of you. The expression of each property can be determined on a 7-point scale (from zero to six). The value "zero" means the absence of this property in the presented sound, and the value "six" indicates the maximum expression of the property in the presented sound. Circle the number which, in your opinion, most accurately describes the expression of the proposed property. After you fill out the list, say "next sound" out loud. In total you will be presented with 32 sounds.

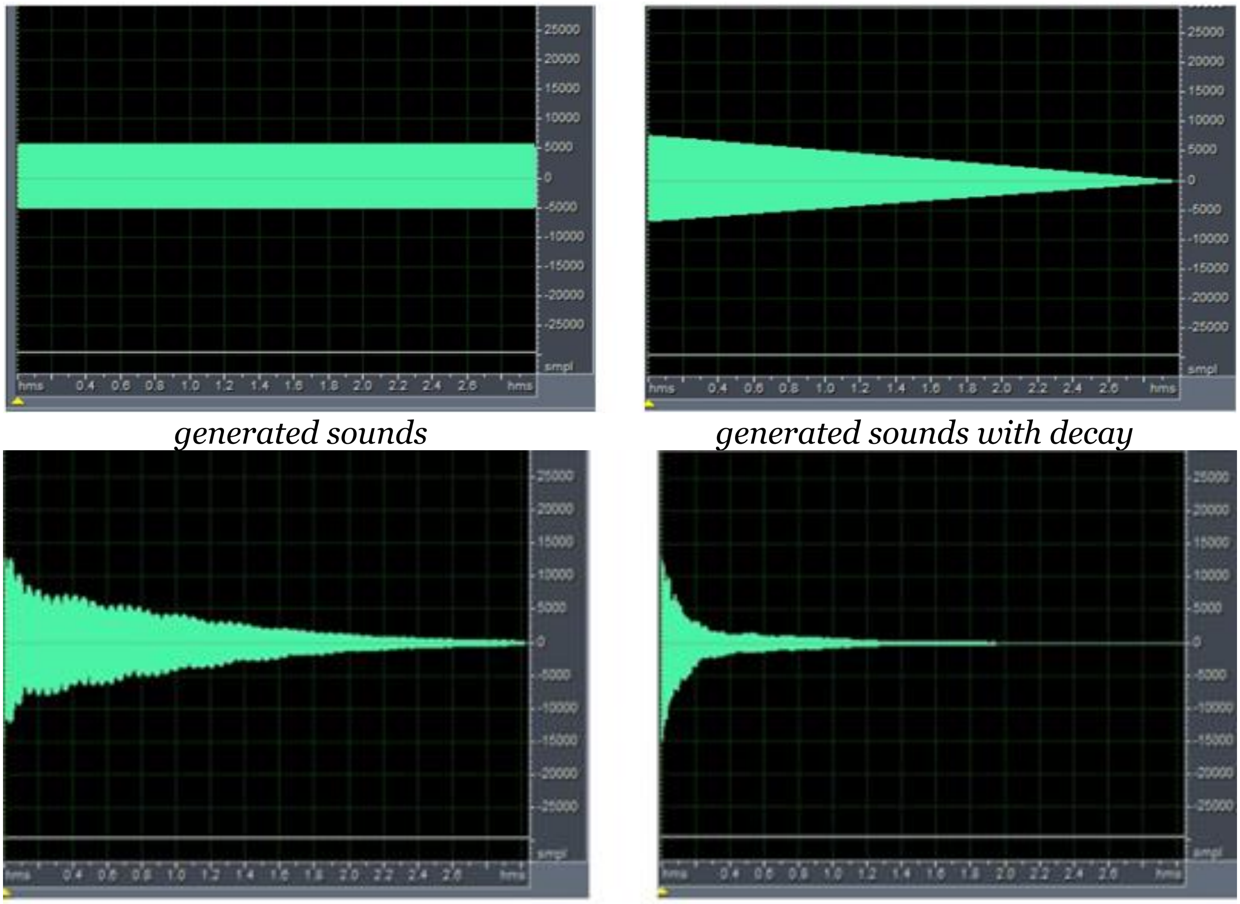
The further procedure is similar to the first study. The experiment with one subject lasted from 50 to 90 minutes, and in the musicians' sample – from one to two hours, depending on the speed of filling in the blanks by them.

After reading the instructions, the subjects were allowed to look at the scales of the semantic differential and ask questions about them. In the sample of musicians there were no questions about the scales. Non-musicians pointed to "Not Major/Major" and "Not Minor/Minor" scales. The experimenter suggested that they should provide associations on these scales. They associated “Not Major/Major” scale with a representative of elite youth. “Not Minor/Minor” scale was difficult for them to provide an association to, so they were offered to rate it as the opposite of “Major”. After the end of the study the experimenter also separately questioned non-musicians on what they know about major and minor keys and chords. Of the entire group of non-musicians, only three subjects were able to associate these concepts with music, but none of them defined them.

B 3. Results

B 3.1. Statistical differences in the evaluation of major and minor chords

A Wilcoxon T-test was used to reveal the differences in estimations of major and minor chords. Significant differences in the ratings of major and minor chords were found in all conditions, with the exception of the ratings of non-decayed generated sounds by non-musicians. This test reveals the presence of differences, but not the direction of evaluations. The subjects could distinguish major from minor triad chords, but ascribe them to a different pole compared to what is usually expected, i.e., they could evaluate a major chord as sad and a minor chord as happy. Generally, in this study the expected poles of evaluations are not inverted, although with a few exceptions. For example, contrary to the expectations non musicians evaluated the minor second type attenuation stimuli as more “positive”, which doesn’t correspond to the traditional description of the minor as the “sad” scale.



generated sounds — *generated sounds with decay* — *MIDI sounds* — *real piano sounds*

Figure 5. The amplitude view of 4 groups of major chords tonic C5. The upper left – the first group – no attenuation. The upper right –the second group – linear attenuation. The lower left –the third group – MIDI amplitude envelope. The lower right –the fourth group – real piano chord amplitude envelope.

Table 3. Unipolar and bipolar semantic differential scales for triad chords evaluation

№	Scale	Unipolar	Bipolar
1	Unpleasant/Pleasant	X	
2	Not tensing / Tensing	X	
3	Don’t want to do something / Want to do something	X	
4	Not heavy / Heavy	X	
5	Not light / Light	X	
6	Not active / Active	X	
7	Not anxious / Anxious	X	
8	Not happy / Happy	X	
9	Not sad / Sad	X	
10	Not expected that something will happen / Expected that something will happen	X	
11	Not warm / Warm	X	
12	Not Major / Major	X	
13	Female / Male		X
14	Not interesting / Interesting	X	
15	Don’t want to mute / Want to mute	X	
16	Not Natural / Natural	X	
17	Languid / Cheerful		X
18	Pessimistic / Optimistic		X
19	Not energetic / energetic	X	
20	Unsure / Sure	X	
21	Not Asking / Asking	X	
22	Not Exciting / Exciting	X	
23	Don't want to help him / Want to help him	X	
24	Not cold / Cold	X	
25	Not Minor / Minor	X	
26	Not Musical / Musical	X	
27	Not good / Good	X	
28	Not hysterical / Hysterical	X	
29	Not Angry / Angry	X	
30	Negative / Positive		X
31	Not boring / Boring	X	
32	Not relaxing / Relaxing	X	
33	Not working properly / Working properly	X	
34	Quiet / Loud		X
35	Young / Old		X

Table 4. Statistically significant differences in the Wilcoxon T-test between evaluations of minor and major triad chords for a sample of non-musicians for all 4 groups of sounds (I - generated without attenuation, II - generated with a linear attenuation, III – MIDI sounds, IV - real sounds)

Non-musicians	**Stimuli type**			
Scale	I	II	III	IV
Unpleasant / Pleasant	n.s.	n.s.	n.s.	n.s.
Not tensing / Tensing	n.s.	n.s.	n.s.	.037883
Don't want to do something / Want to do something	n.s.	n.s.	n.s.	n.s.
Not heavy / Heavy	n.s.	n.s.	n.s.	.000651*
Not light / Light	n.s.	n.s.	n.s.	.000199**
Not active / Active	n.s.	n.s.	n.s.	n.s.
Not anxious / Anxious	n.s.	n.s.	n.s.	.000410*
Not happy / Happy	n.s.	n.s.	n.s.	.000010***
Not sad / Sad	n.s.	n.s.	n.s.	.000011***
Nothing will happen / Something will happen	n.s.	n.s.	n.s.	n.s.
Not warm / Warm	n.s.	.044	.045	.000106**
Not Major / Major	n.s.	n.s.	n.s.	.000313*
Female / Male	n.s.	n.s.	n.s.	n.s.
Not interesting / Interesting	n.s.	n.s.	n.s.	.012518
Don't want to mute / Want to mute	n.s.	n.s.	n.s.	.015222
Not Natural / Natural	n.s.	n.s.	.044	n.s.
Languid / Cheerful	n.s.	n.s.	n.s.	*.058050*
Pessimistic / Optimistic	n.s.	n.s.	n.s.	.000059**
Not energetic / Energetic	n.s.	n.s.	n.s.	.024844
Unsure / Sure	n.s.	n.s.	n.s.	.002164
Not Asking / Asking	n.s.	n.s.	.021	.030679
Not Exciting / Exciting	n.s.	n.s.	n.s.	n.s.
Don't want to help him / Want to help him	n.s.	n.s.	n.s.	.035131
Not cold / Cold	n.s.	.012	n.s.	.000851*
Not Minor / Minor	n.s.	n.s.	n.s.	.002246
Not Musical / Musical	n.s.	n.s.	n.s.	.961166
Not good / Good	n.s.	n.s.	n.s.	.000314*
Not hysterical / Hysterical	n.s.	n.s.	n.s.	.022015
Not Angry / Angry	n.s.	.016	n.s.	.011046
Negative / Positive	n.s.	.025	n.s.	.000048**
Not boring / Boring	n.s.	n.s.	n.s.	n.s.
Not relaxing / Relaxing	n.s.	n.s.	n.s.	.042932
Not working properly / Working properly	n.s.	n.s.	n.s.	.024300
Quiet / Loud	n.s.	n.s.	n.s.	n.s.
Young / Old	n.s.	n.s.	n.s.	.026731

n.s. – non significant
Italic – tendency,
** – Bonferroni correction for 35 measures at p<.05,*
*** – the same at p<.01,*
**** – the same at p<.001.*

Table 5. Statistically significant differences in the Wilcoxon T-test between evaluations of minor and major triad chords for a sample of musicians for all 4 groups of sounds (I - generated without attenuation, II - generated with a linear attenuation, III – MIDI sounds, VI - real sounds)

Musicians	**Stimuli type**			
Scale	I	II	III	IV
Unpleasant / Pleasant	.006662	n.s.	.0054859	.039044
Not tensing / Tensing	*.051298*	n.s.	n.s.	n.s.
Don't want to do something / Want to do something	n.s.	n.s.	*.0507406*	n.s.
Not heavy / Heavy	n.s.	n.s.	.0245646	n.s.
Not light / Light	.009252	n.s.	.0008613*	.000178**
Not active / Active	n.s.	n.s.	.0152603	.002350
Not anxious / Anxious	.000422*	n.s.	.0018495	.000011***
Not happy / Happy	.000858*	.016	.0000017***	.000006***
Not sad / Sad	.001593	n.s.	.0000004***	.000001***
Nothing will happen / Something will happen	n.s.	n.s.	n.s.	n.s.
Not warm / Warm	.020372	.039	.0139637	.000146**
Not Major / Major	.000051**	.002	.0000003***	.000001***
Female / Male	n.s.	n.s.	.0156959	n.s.
Not interesting / Interesting	n.s.	n.s.	.0472738	n.s.
Don't want to mute / Want to mute	n.s.	n.s.	n.s.	.038204
Not Natural / Natural	n.s.	n.s.	n.s.	.028645
Languid / Cheerful	n.s.	n.s.	.0003674*	.002162
Pessimistic / Optimistic	.011288	.004	.0000024***	.000037***
Not energetic / Energetic	*.051403*	n.s.	.0000933**	.000605*
Unsure / Sure	*.066575*	n.s.	.0002331**	.002584
Not Asking / Asking	.004287	.017	.0000336**	.000061**
Not Exciting / Exciting	n.s.	n.s.	*.0574366*	.004044
Don't want to help him / Want to help him	.000437*	.047	.0070508	.018243
Not cold / Cold	.000054**	n.s.	.0000028***	.000176**
Not Minor / Minor	.000182**	.008	.0000001***	.0000001***
Not Musical / Musical	n.s.	n.s.	n.s.	n.s.
Not good / Good	n.s.	.013	.0066173	.002349
Not hysterical / Hysterical	.048354	n.s.	n.s.	.026748
Not Angry / Angry	.004924	n.s.	.0249653	.048309
Negative / Positive	n.s.	n.s.	.0007896*	.000055**
Not boring / Boring	n.s.	n.s.	.0048445	n.s.
Not relaxing / Relaxing	.031273	.015	n.s.	.040688
Not working properly / Working properly	n.s.	n.s.	n.s.	n.s.
Quiet / Loud	n.s.	n.s.	*.0504039*	.005490
Young / Old	n.s.	n.s.	n.s.	.000437*

n.s. – non significant
Italic – tendency,
** – Bonferroni correction for 35 measures at p<.05,*
*** – the same at p<.01,*
**** – the same at p<.001.*

B 3.2. Factor analysis

A factor analysis was conducted, with an extraction of the main components, and the "Varimax", raw values method of rotation. According to the results of the Scree test, in the sample of non-musicians 4 factors are identified, explaining 52% of the variance of subjects' evaluations.

The first factor "General tension" explains 29.35% of the variance. Factor loadings are shown in Table 6. The second factor, "Activation," explains 11.45% of the variance. Factor loadings are shown in Table 7. The third factor "Minor" explains 6.1% of the variance. Factor loadings are shown in Table 8. The fourth factor «Major» explains 4.46% of the variance. Factor loadings are shown in Table 9.

According to the results of the Scree test, in the sample of musicians 3 factors were identified explaining more than 63% of the variance of subjective estimations. The first factor "Extended semantic description of major/minor" explains 36.16% of the variance. Factor loadings are presented in Table 10. The second factor "Extended Generalized tension" explains 16.59% of the variance. Factor loadings are presented in Table 11. The third factor "Affiliative Excitement" explains 9.39% of the variance. Factor loadings are presented in Table 12.

Table 6. Factor loadings of the first factor in the sample of non-musicians (values of more than 0.7 and less than -0.7 are highlighted)

Factor 1	Factor loadings
Unpleasant / Pleasant	**.79**
Not good / Good	**.79**
Negative / Positive	**.77**
Not light / Light	**.71**
Not happy / Happy	**.71**
Not relaxing / Relaxing	.68
Pessimistic / Optimistic	.67
Not interesting / Interesting	.64
Not musical / Musical	.64
Not Natural / Natural	.58
Not working properly / Working properly	.37
Not warm / Warm	.7
Not cold / Cold	-.51
Not boring / Boring	-.55
Not Angry / Angry	-.65
Not heavy / Heavy	-.66
Not tensing / Tensing	**-.7**
Don't want to muffle it / Want to muffle it mute	**-.71**

Table 7. Factor loadings of the second factor in a sample of non-musicians

Factor 2	Factor loadings
Not energetic / Energetic	**.82**
Unsure / Sure	**.74**
Not Exciting / Exciting	**.71**
Not active / Active	.68
Quiet / Loud	.51
Sluggish/Cheerful	.8
Not sad / Sad	-.38

Table 8. Factor loadings of the third factor in the sample of non-musicians

Factor 3	Factor loadings
Not pleading / Pleading	.61
Don't want to help it / Want to help it	.61
Not minor / Minor	.53
Not expected that something will happen / Expected that something will happen	.52
Not hysterical / Hysterical	.48
Not anxious / Anxious	.46
Don't want to do something / Want to do something	.44

Table 9. Factor loadings of the fourth factor in a sample of non-musicians

Factor 4	Factor loadings
Female / Male	**.71**
Young / Old	.55
Not major / Major	.37

Table 10. Factor loadings of the first factor in the sample of musicians

Factor 1	Factor loadings
Pessimistic / Optimistic	**.86**
Not warm / Warm	**.77**
Not good / Good	**.76**
Not Major / Major	**.75**
Negative / Positive	**.74**
Unpleasant / Pleasant	**.73**
Not light / Light	**.71**
Languid / Cheerful	.68
Not energetic / Energetic	.67
Not working properly / Working properly	.61
Unsure / Sure	.59
Not relaxing / Relaxing	.54
Not Exciting / Exciting	.47
Not natural / Natural	.47
Not happy / Happy	.8
Not interesting / Interesting	.7
Don't want to mute / Want to mute	-.7
Not heavy / Heavy	-.54
Young / Old	-.57
Not tensing / Tensing	-.59
Not angry / Angry	-.63
Not cold / Cold	-.66
Not boring / Boring	-.67
Not anxious / Anxious	-.68
Not sad / Sad	-.68
Not minor / Minor	**-.73**

Table 11. Factor loadings of the second factor in the sample of musicians

Factor 2	Factor loadings
Not active / Active	.55
Quiet / Loud	.51
Nothing will happen /Something will happen	.49
Not hysterical / Hysterical	.45
Female / Male	.23

Table 12. Factor loadings of the third factor in the sample of musicians

Factor 3	Factor loadings
Don't want to help it / Want to help it	**.71**
Not pleading / pleading	.55
Not Musical / Musical	.49
Do not want to do something / Want to do something	.46

4. Discussion

The results of the first study show that the subjects without a musical education cannot differentiate the emotional valence of the major and minor triad chords on the basis of tonal characteristics alone. The scales for which sounds were differentiated, are either not associated in scientific literature with the recognition of major and minor keys (“Narrow / Wide”), or their estimations are inverted (in the scales “Passive / Active” and “Boredom / Interest” the major is both “passive” and “boring”). For the full perception of musical sound filled with emotional semantics, other characteristics besides the tonal are required. They were revealed in the second study, when non-musicians first recognized emotional valence of generated sounds in the case of linear attenuation (“Negative / Positive” scale). In this case, the estimations are again inverted, as minor triad chords are evaluated as positive. It is worth paying attention to the scale "Not warm / Warm" within the comparison of the second and the third group of sounds. Non musicians can differentiate major and minor chords both generated with a linear attenuation and MIDI by this scale. Nevertheless, in the second group of sounds their estimations are inverted, and in the third group they correspond to cultural expectations. These two groups of sounds differ in the nature of attenuation (in the case of MIDI it is not linear and closer to the inverse power dependence), as well as in the presence of overtones in MIDI, although they are less expressed than in real sounds of musical instruments. We can assume that the presence of attenuation (albeit linear) is the basis for the appearance of emotional semantics of a sound, but it is not sufficient for the correct recognition of polarity of emotions. In their turn, the overtones complement the attenuation, allowing correct recognition of the emotional valence direction.

Professional musicians are able to cope with the task already in the group of triad chords generated without intensity attenuation. They also demonstrate increase in the accuracy of major and minor recognition from the first to the third and fourth group of sounds, with the exception of hardly ever heard second group of the sounds. The average time it took musicians to accomplish the task was longer than that of non-musicians. Several subjects in this group spent more than two hours filling out the semantic differential, while all of them were subjectively more tired. All of the participants of the professionals group noted that sounds consisted of major and minor chords.

The data can be interpreted as indicating the presence of different psychological mechanisms of major and minor chords perception within the samples of non-musicians and musicians. People with musical education and experience in playing musical instruments can differentiate major and minor chords and correctly evaluate their valence basing exclusively on the tonal component. Unlike them, non-musicians need the presence of intensity attenuation as well as the overtones for the correct emotional valence connotation. Nevertheless, in the case of the real piano sounds both groups show similar results.

The role of the sound intensity attenuation in recognition of major and minor triad chords is the decisive one. Its presence first makes possible for non-musicians to distinguish between major and minor keys and enhance corresponding capabilities in professionals in up to 2.6 times. It is impossible to distinguish major and minor keys basing solely on the tonal component without special professional education and training. Moreover, training of a semiprofessional level with the lack of regularity may be not sufficient. Presence of amplitude envelope that is specific for musical sounds almost equals abilities of non-musicians and professional musicians in recognition of the major and minor chords. A linear attenuation of the sound's intensity influences non musicians and music professionals differently: it helps the first and confuses the last.

Results of this research confirm the data of several studies on the ability of non-musicians to correctly differentiate major and minor keys. Our work clarifies the role of amplitude envelope in this phenomenon.

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Highlights:

- Aim is to study subjects' ability to evaluate emotional valence of chords based on their tonal and amplitude characteristics.
- Stimuli consist of generated and played by piano major and minor triad chords.
- The total of 103 amateurs/non musicians and professional musicians participated.
- Set of subjective scales was used for the evaluation of stimuli.
- Amplitude decay is crucial for the perception of emotional valence of chords in non-musicians.
- Professional musicians are able to perceive chords emotional valence without amplitude decay.
- Amplitude decay enhances perception of chords emotional valence in professionals.

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