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PROCEEDINGS

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The Impact of Long-Term Playing of a Musical Instrument on the Perception of Acoustic Phenomena in Aural Skills Training

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Abstract

This research deals with the differences in audiation and aural perception of acoustic phenomena (pitch, key) in aural skill training between players of different types of instruments in ear training classes. The research included string, keyboard, wind, and percussion instrument players. Semi-structured interviews were conducted, after which an online questionnaire with open ended questions was applied. The inductive qualitative analysis aimed to identify relationship among data. It revealed that the long-term playing of certain musical instruments significantly impacts the process of perception and cognition depending on the instrument's construction, the way the sound is produced, and the difficulty in controlling intonation. Certain cognitive actions are more developed depending on the instrument a student plays, which has a greater impact on the perception process. String players develop a high timbre sensibility, keyboard players cultivate strong music mental imagery, while wind players are focused on internal processes related to the way the sound is produced on their instrument, which is highly abstract. Developing insights into how students understand and perceive acoustic phenomena has important implications for developing the music curriculum in formal education, which could result in more successful encouragement and guidance in developing musical skills.

Introduction

Every human is able to 'hear' music the same as every musician does. What distinguishes musicians is not their ability to hear but their understanding and comprehension of what they hear. These cognition actions involve different processes which become apparent, especially in aural skill training, and are articulated through the work of music pedagogues and music psychologists. Edwin E. Gordon (1997) and Gary Karpinski (2000) defined the terms 'audiation' and 'auralizing', which essentially refer to the ability to think in/about music by giving meaning to sound. Even before Gordon, the complete educational philosophy of the Hungarian pedagogue Zoltán Kodály was based on the development of 'inner hearing' (see Kazić, 2013). Lipscomb (1996) observed similar thoughts regarding aural sensibility. Using the term 'apperception', he argued that music is stored in our memory in a different form than its acoustic properties, indicating the importance of previously obtained knowledge and experience. These processes should not be confused with aural perception but they occur simultaneously, so the research emphasized perception and cognition actions.

In aural skill training, it becomes evident that these processes are highly internal and exceptionally subjective. No matter how equally students are trained in aural skills, and all of them use the same standardized symbolic musical language, they engage with music through the instrument they play, and they think and perceive from the perspective of their instrument.

Aims

The research aims to examine the differences in perception (pitch and key) and cognition processes (audiation) in aural skills training between players of different instruments. The intention is to provide initial observations and reflections, based on which the research could be further expanded within the framework of music pedagogy.

Research Method

Sample

The sample consists of 53 respondents, while 7 were excluded from the analysis due to methodological reasons (did not fit to research participation criteria, or gave incomplete answers). The respondents were students who were enrolled in music performance studies (undergraduate and graduate programs), and recruited from the Music Academy of the University of Sarajevo. These respondents each have 9 to 15 years of specialized music education and experience regarding the instrument they play. The number of players (N = 53) for each instrument individually are displayed in Table 1.

Table 1. Sample overview according to the instrumental groups and instruments respondents play.

String instruments		Keyboard instruments		Wind instruments	
Violin	3	Piano	10	Clarinet	5
Viola	3	Accordion	10	Flute	5
Cello	2			Trumpet	4
Contrabass	1			Trombone	1
Guitar	5			Saxophone	4
n = 14		n = 20		n = 19	
Total n = 53					

Procedure

The research had two subsequent phases. First, semi-structured interviews were conducted in 4 groups, organized by study years, regarding phenomenological aspects (e.g., audiation, subjective pitch, and tonality experiences) with an intention to detect the main differences in perception and cognition among students who play instruments from different instrumental families. Based on the results of the first exploratory phase, an online survey consisting of open-ended questions was created. The survey contained introductory questions concerning the musical background, instrument of interest, and absolute or relative pitch ability report. In alignment with the purpose of the research, we developed the following open-ended questions:

1) Do you consider any pitch or key (tonality) as the basic one? Why?
2) Can you recognize a certain pitch or key (tonality) without a reference? Explain.
3) Do you consider enharmonic equivalents as same? Why?
4) While listening and trying to hear, and recognize a pitch, interval or chord, do you associate them with: a notation system, keyboard, or something else (Explain). Why?

The survey was entirely anonymous, and any inadvertent information respondents provided was anonymized to protect their privacy.

Data Analysis

Respondents self-reported their internal processes. Therefore, the research deals with inductive qualitative, in-depth analysis, which gives a good understanding of the research problem. Presentation and interpretation of results on 4 questions are organized by instrument families (strings, keyboards, and winds), where data given by players of different instruments were analyzed individually or separately as a subgroup. Within the results' sections, data are presented according to the research questions, and by the end of each section, nontypical responses are separately described.

Results

String Players

In the string group, the violin, viola, cello, and contrabass (bowed strings) players' responses will be discussed first. The observed answers of guitarists (plucked strings) will be discussed separately as the difference in the instrument's construction leads to differences in the answers, which are easier to follow when separated.

The answers given by violin, viola, cello, and contrabass players clearly were related to their instruments. In the first question (Do you consider any pitch or key [tonality] as the basic one? Why?) all respondents highlighted pitch A, the reference to tune their instrument, as the basic pitch. Basic keys are considered A major and D major, described as most comfortable (finger positions are more natural), where open strings, which are readily available to be used, deliver lots of resonance.

While answering the second question (Can you recognize a certain pitch or key [tonality] without a reference? Explain.), all respondents stated they could recognize pitch A without a reference. Among the answers, open strings (pitches G, D, A, E) were also mentioned (in the first question as well), but this pitch recognition was described as accurate only regarding their own instrument. The pitch memory is linked to the timbre of the instrument they play. One respondent, a violin player, stated that recognizing G, D, A, E, in his case, is accurate. also while listening to other instruments, he just imagines how the pitch (played on any instrument) would sound on the violin, and based on this 'timbre idea' he is further able to distinguish the pitch. It is interesting how the pitch, regardless of its timbre quality, is linked to a corresponding violin timber in order to be recognized.

In the third question, concerning the enharmonic equivalents (Do you consider enharmonic equivalents as the same? Why?), the respondents further confirm the importance of their instrument as a perceptual framework. Good intonation on string instruments requires constant demand for attention where the pitch is tuned not only as an isolated tone but it also refers to tonality, harmony, and phrase. Consequently, enharmonic equivalents are played with different finger positions and sometimes on different strings. In this regard, all respondents stated that there is a significant difference regarding the tone color of the 2 enharmonic equivalents, which is why they are considered different notes and different pitches.

The guitar players, just like other strings, in the first question (Do you consider any pitch or key [tonality] as the basic one? Why?) mentioned the pitch reference for tuning as the basic pitch, which in their case is E. The basic key is considered E major. Interestingly, respondents were leaning towards major tonality even if the guitar is tuned leaning towards E minor. Ernst Terhardt's theory predicts that the minor triad has a more ambiguous root than the major triad (see Parncutt, 2014), which could explain the above mentioned responses. Regarding the question about pitch and key, the respondents gave similar explanations to the bowed string players. The difference is only observed in the exact mentioned pitch and key related to the instruments' typical characteristics.

Answering the second question (Can you recognize a certain pitch or key [tonality] without a reference? Explain.), all the guitarists stated that pitch E can be recognized without a reference tone. One of the respondents described this pitch-memory processing in more detail. He explained that pitches around E sound with certain colors, but only E is 'colorless', not giving a negative connotation, on the contrary, E is perceived as neutral, meaning basic. Another respondent stated that he can recognize any pitch from E1 to B3 (American E4 to B6), regardless of the chosen finger position and string, played single or in a chord, but only on the guitar; if reproduced on other instruments, his accuracy would be questionable.

Answers of the guitar players on the third question (Do you consider enharmonic equivalents as the same? Why?) pointed out the major differences compared to bowed strings players. They stated that enharmonic equivalents sound the same and that no specific acoustic difference exists. The explanation for this sudden change lies in the very construction of the instrument. The frets on the guitar's neck physically touch the strings regardless of finger position, which makes the strings less sensitive to minor finger movements. In contrast, even minor fingering changes affect the intonation on fretless string instruments much more.

While answering the last question (While listening and trying to hear and recognize a pitch, interval, or chord, do you associate them with: a notation system, keyboard, or something else [Explain]. Why?) all string players mostly stated that they usually rely on the notation system in the perception process. Considering that they cannot experience the playing process visually and cannot see their fingers while playing, the notation system gives them the visual support they might need. Some respondents answered *something else:* instinctively imagining playing the instrument and associating with the finger positions, strings, and especially timbre.

Other answers. Two respondents, a violinist, and a guitarist, answered quite differently regarding the first question pointing out that C major would be their basic key. All respondents were trained in the Balkan area, where formal music education usually begins at the age of 8 and offers systematic tuition in instrument playing and in ear training with music theory. Regarding music theory, pupils are first introduced to the C major scale in accordance with the curriculum. Throughout music theory history, from Zarlino to today, it is generally thought of as the 'default' major scale because it is easy to read as it does not have any sharps and flats. Therefore, though answering C major is understandable, it cannot be neglected that it is visually the most adaptable key. However, most respondents have shown no reference to C major, affirming the perception that is being cultivated among players of the same instrumental group.

Keyboard Players

In the keyboard group, the answers of piano and accordion players are analyzed together since no striking differences were observed between their responses. Considering the first question (Do you consider any pitch or key [tonality] as the basic one? Why?), piano players mostly highlighted C as the basic pitch and C major as the primary key. C major is the most accessible key to 'think' in; however, the most difficult to get 'under the fingers' and the least natural for the hand. Still, respondents answers based on what they see; they distinguish C major as the tonality without black piano keys. This visual impact was also confirmed by the answers of accordion players, all of whom play the keyboard accordion. We could say that the keyboard, in some way, visually determines the musical space with which the players identify. But the further question would be, is this visual perception impact linked to aural perception?

In the second question (Can you recognize a certain pitch or key [tonality] without a reference? Explain.), none of the respondents mentioned recognizing pitch C, nor having any aural sensibility towards the C major tonality. In general, no specific answers were given, either by piano or by the accordion players. In addition, some of the respondents stated that they do not occupy themselves with these tone qualities. The same attitude was also observed in the third question (Do you consider enharmonic equivalents as the same? Why?). They revealed that the difference between enharmonic equivalents is understood only theoretically. Respondents were aware of the difference regarding notation and the function of the pitch in tonality. However, respondents were not completely familiar with the acoustic difference. They visually associated a note with a certain piano key and stated that the enharmonic equivalents sound the same: the same pitch, the same key. They further explained that they find it hard to hear the difference even when listening to a non-tempered instrument or while singing.

In the final question (While listening and trying to hear and recognize a pitch, interval, or chord, do you associate them with: a notation system, keyboard, or something else [Explain]. Why?), as expected, with only a few exceptions, respondents mostly answered they associated pitch, interval, or chord with the keyboard, which clearly confirms the visual link to the instrument. Respondents explained that the psychical touch of the keyboard and the learned spacing between notes on the keyboard offers certain support, essential in the process of audiation.

Other answers. One respondent, an accordion player who plays the accordion with a standard bass (button board which uses columns of buttons arranged in a circle of fifths), gave an interesting response to the second question, which we will quote:

> I am able to recognize all root tones of the circle of fifths. Long-term practice, the inability to visually perceive the left hand and relying only on my ear led to memorizing positions in the bass which unconsciously led to pitch memorizing.

The respondent clearly indicated that visual stimuli can also hinder aural perception.

Wind Instruments

The wind group involves brass and woodwind players whose answers will be discussed all together, except the saxophonists, whose answers were found to be different and specific and will be explained separately at the end of the section.

In the first question (Do you consider any pitch or key [tonality] as the basic one? Why?) wind players mostly highlighted pitch C and C major as the basic key. Still, here we must point out that this mentioned C has no relation with the C of keyboard players (no visual relation), and there are also differences behind the answers given by players of each wind instrument. Flute players lean towards C, because the instrument is pitched in C, and it is also the lowest pitch on the instrument. Other wind players gave similar answers. But in their case, considering that they play instruments pitched in the B flat key, when responding that C is major pitch, they were indicating to the sounding B flat and B flat major. Trumpet players gave answers that share some similarities with strings. When playing the trumpet without using piston valves, the overtone series starts from B flat, and respondents explained that the instrument sounds more natural and resonates better in B flat. This timbre quality is considered significant for trumpet players as well as for the strings.

Regarding the second question (Can you recognize a certain pitch or key [tonality] without a reference? Explain.), the respondents gave answers quite the opposite of those previously mentioned. Flute players did not mention any specifics, while clarinet, trumpet, and trombone players answered that they can always recognize pitch A, the tuning reference. In the case of clarinet players, the answers trigger curious thoughts. Their instrument is tuned in B flat, and they play in B flat major most frequently, but they tune their instrument on A, which is the seventh degree in the key of B, the most unstable degree which tends to resolve to the tonic (to B flat). Therefore, the A as a tuning reference does not match the A in the key of B flat major, and they are acoustically different. The question is, how is pitch A further tuned? Would another pitch be more adequate as a tuning reference?

Respondents answered pretty diversely to the third question about enharmonic equivalents (Do you consider enharmonic equivalents as same? Why?), and there was a similar number of those who consider them as same, and those who do not. Speaking about all wind instruments, the enharmonic equivalents are often played on the same position, with same finger charts, which is why some respondents relate to that finger motor command and consider them the same. However, the enharmonic equivalents, regardless of the same fingering possibilities, are the matter of intonation, at last, controlled by the players themselves. The fingering chart brings them to a certain point from which the player further directs and adjusts the pitch by embouchure and airflow control. We could say that on wind instruments, the musical spaces are in a certain way determined (finger charts, motor commands), but it is also very abstract and relies on the musical intuition of the player, which results in diverse answers depending on the ability of the player to aurally represents this difference. Speaking in particular about the trumpet, which has the least finger chart combinations, the process of playing the trumpet is highly abstract, and if we take into consideration the process of how they get

to a particular pitch and considering that they do not produce the sound that is equivalent to the one they see in their sheets, a question like these can be very confusing for them.

On the final question (While listening and trying to hear and recognize a pitch, interval, or chord, do you associate them with: a notation system, keyboard, or something else? [Explain]. Why?), the most common answer was *something else* which usually referred to the reproduction of the sound on the instrument, like finger chart positions, embouchure setting, but very importantly the breathing motor commands. One of the trumpet players explained this a little bit closer, which is why we will quote it: "While trying to recognize a certain interval, I imagine playing that interval on the trumpet, I start to blow air, and based on the intensity of the airflow that I would instinctively need to produce that certain interval I can determine which interval it is." Many players wrote that they usually rely on their instrument but found it hard to explain how.

The answers among the respondents who play the saxophone were very different, so it was difficult to treat them together with other winds. Each respondent gave very diverse answers to each question, and no specific perceptual similarities were found among respondents. One of the reasons could be that they all frequently play different types of saxophones, pitched in different keys, resulting in various answers.

Discussion

The string players' answers trigger thoughts about how pitch and timbre interact within the memory. It is clear that in long-term pitch memory (if specific pitch memory exists), timbre and pitch are stored as a unit. Timbre, as the essential perceptual category for string players, does not emerge only as a distinction between the acoustic qualities of sound between the different musical instruments but also as a whole 'timbre pallet' obtained on their instrument (distinguishing of enharmonic equivalents).

Recent studies locate timbre on the perceptual side of the 'psychophysical divide', i.e., in the listener's mind instead of in physical properties (Siedenburg, 2016). In this regard, timbral qualities become even more apparent as a result of self-assessing the intonation of the instrument, where differences between the guitarist and other string players were observed, since the intonation on the guitar is easier to control in comparison to bowed string instruments. This becomes even more evident when comparing the answers of string players with those of equal-tempered instruments discussed in the keyboard section. Auditory imagery is not linked to their instrument since the body posture makes it hard to follow the fingers while playing visually. This is why the mental images of pitch relations are linked more to the notation system.

For keyboard players, no concrete pitch and timbral sensitivity were observed. Their perception and cognition processes rely more on visual abstractions. The playing comfort is also not given special importance, which was, on the other hand, very significant for the strings, as it provides better intonation control and affects other tone qualities. However, the piano is equal-tempered, and even if the playing comfort does not make a difference regarding intonation, it can influence other tone qualities. The definition of tone quality given by Helmholtz (Helmholtz, 1895, p. 3) is directed towards the distinctive nature of the sound produced by 2 different instruments, which determines the meaning of timbre for a long period of time. However, more recent studies indicate the shortcomings of this, highlighting the importance of playing technique, articulation, and playing effort which raises the timbral properties of a tone (Barthet et al., 2010; McAdams et al., 1995). Chopin considered that even every finger produces a different tone color "as many different sounds as there are fingers" prizing their natural inequality as a source of various sounds (Cortot, 2013, p. 46). Research has proven bodily enactment of timbre intentions and the close association of the perceived

timbre outcome with bodily production (Li & Timmers, 2020). However, no specific parallel between timbre and pitch or key recognition has been observed during the research. Their perception and cognition processes are more determined by visual abstractions and mental imagery.

The perception process in wind players is linked primarily to the way sound is produced on the instrument by breathing. While playing, breathing is delivered through a sophisticated interface with the instrument, through action from muscles of expiration, embouchure imprints, blowing pressure, and airflow (Fuks & Fadle, 2002). Breathing is a physical activity in its own nature, but also a sensation intuitively received into consciousness. This abstraction is why the respondents found it very hard to translate the processes included in the perception process into words.

Conclusion

The research has shown that music perception and cognition are influenced by playing experience, where the same or similar answers were observed among respondents with the same preference for a particular musical instrument and otherwise.

The results assume that there is a primary key in the sense of an auditory feature readily perceived but also as a structure obtained through the notation system. We further conclude that if existing, the basic key emerges as a 'psychological key' that is not exclusive but cultivated through musical endeavors on an instrument. Additionally, these musical endeavors contribute to awareness of absolute pitch and pitch sensibility, particularly regarding the instrumental performance experience in non-tempered instruments. We conclude that a musical mind is primarily guided by active processes such as performing instead of learning theoretical aspects of music. All perception and cognition occur in context, and the long-term experience of playing a musical instrument is important when motor systems are recruited together with auditory systems. We believe that our findings are of universal significance and offer diverse implications for future research in music psychology and ear training pedagogy.

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