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Sources of individual differences in human musical activity: selected neurophysiological and developmental aspects[1]

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Abstract: The article is devoted to individual differences in the field of human musical activity. Musical abilities were taken into account in terms of development, emphasizing the prenatal period of a man. The attention was paid to important aspects in further human development, taking into account heritability and the influence of the environment. They used neurophysiological indicators of changes in development that define neuroplasticity. The importance of characteristics relating to perception, musical intelligence and manual skills was also noted. It is also associated with individual differences in physical activity as a response to music or support in musical performance. The importance of own work in the development of musical abilities was also taken into account. It turns out to be equally important to emphasize the development of musical abilities within the recalling game as opposed to the improvisational one, which is correlated with the variable activation of the neurophysiological task-positive and task-negative networks. The cross-sectional approach to the problem shows the complexity of the musical activity itself which justifies the wide variance of musical abilities analyzed in terms of individual differences which underlie the neurophysiological mechanisms conditioning developmental changes and resulting from own work.
Keywords: improvisation, individual differences, musical abilities, musical activity, musical intelligence, neuroplasticity

Introduction

The aim of this study is to present a review of selected issues concerning individual differences in musical ability[2]. Individual differences are physical and mental traits or generalized tendencies to specific behaviors that are relatively constant within the individual. These include: abilities, including intelligence, personality and temperament, cognitive styles, styles of coping with stress. Individual differences researchers generally focus on two trends: neurobiological (including genetic), and cognitive (Strelau, Zawadzki, 2016). Both include dynamics during developmental processes that include environments such as family, peers or the child's school environment. Our aim was to examine the phenomenon of musical abilities from two different perspectives: first, neuroscience, or the physical perception of sounds by humans and their physiological response to sound stimuli, and second, the science of human development which includes children's music education.

We considered the concept of human musical activity to include both sound perception and body movements, including aspects of fine motor skills

1 Article in polish language: Źródła różnic indywidualnych w aktywności muzycznej człowieka: wybrane aspekty neurofizjologiczne i rozwojowe https://www.stowarzyszeniefidesetratio.pl/fer/2023-3Sweb.pdf

2 The article is the result of the work of students of the Chopin University of Music doctoral school in Warsaw as part of the subject "Psychology of music with elements of the theory of cognition".

closely related to proprioception. In addition, we distinguished abilities such as sight reading and improvisation. In this review, we chose to focus on a broader examination of the literature across neuroscience and music education rather than a complete in-depth review of a single aspect of musical ability. The didactic aspect of this study is intended to service an audience of both musicians and researchers, who want to broaden their general knowledge of individual differences in human musical activity.

The paper is a narrative literature review in which the choice of literature, as already noted above, focuses on research on the neurophysiological mechanisms of human musical activity and research on human development in the context of child music education. As such, the following topics will be discussed in this article: early musical development, potential and development of abilities, musical abilities and neurophysiology, body movement to music – rhythmic interpretation, manual skills, training – own work, playing from notes and improvisation. It is therefore evident that musical activity is multifactorial. This, in turn, makes the development of musical abilities long-term, multifaceted and at the same time dependent on many environmental factors affecting the neurophysiological mechanisms underlying musical activity. It should therefore be expected that there are a number of individual differences in the various dimensions of musical ability.

1. Early musical development

Maria Manturzewska and Barbara Kamińska distinguished six periods of human musical development: prenatal period, infancy period, post-infancy period, pre-school age, younger school age and adolescence, as based on the periodization proposed by Maria Żebrowska, (Manturzewska, Kamińska, 1990). Although we can distinguish individual periods by considering their duration, as well as age, the transition to the next phase of development is determined by individual differences. The prenatal period is the first stage of human psychophysical development, in which the first sensory and motor reactions to music are formed. In the prenatal period, this is done indirectly through the psychophysical state of the mother. Connecting with music can provide the expectant mother with satisfaction and relaxation. This has a significant impact on the development of the child because other negative physiological changes taking place in the mother's body are potentially aversive stimuli for the child. Musical stimulation in the prenatal period however, has a positive effect on development. Among the positive aspects, we can mention that correlations have been found for: greater calmness after birth, better food intake, concentration on objects, greater watchfulness (special attention), faster speech development, as well as greater general developmental efficiency, creative abilities, a higher level of sensitivity and more effective development of cognitive processes (Kędziora, 2012). Thanks to the study of the prenatal period in terms of musical activity, we can see far-reaching positive associations that have impacts on development. It can therefore be concluded that the conditions of the prenatal environment will be the first factors affecting the neurophysiological mechanisms underlying individual differences in various human abilities, including musical ability.

2. Potential and ability development

According to Edwin E. Gordon (Manturzewska, Kamińska, 1990), the causes of individual differences in musical activity are rooted in genetic conditions. Each child has a certain potential for musical abilities which provide opportunities to learn music and develop music-related skills (Bonna, 2005). Musical activity is the result of a musical potential activated by an environment that constantly stimulates music development. Gordon points out, however, even in a favorable environment (e.g.: musical family, musical education), musical abilities may reach their potential but will not exceed it. Similar conclusions were also reached by Howard Gardner who emphasized that various types of intelligence (including musical) are based on a biological potential conditioned by genetic factors (Gardner, 2002).

While researchers are still inconclusive about the heritability of musical abilities, they agree that the child's environment in the first months of its life

has a huge impact on the development of musicality. Psychologist and music therapist Kinga Lewandowska showed that children described as "less musical" come from families where interest in music was very low. Children are not given any patterns of music perception which is why they show low sensitivity to it, they are unable to repeat the melody or rhythm they hear, and when singing they do not intuitively strive for the tonic (Lewandowska, 1978). Put in the same situations, the "more musical" children dance, sing, hum, and react emotionally.

Other researchers came to similar conclusions: Edwin Gordon, Barbara Kamińska and Maria Manturzewska showed that children who have contact with music from an early age show more advanced musical activity as older children, teenagers or adults. One of the functions, according to Gordon's theory, is audiation, which "is to music what thinking is to language" (Bonna, 2005). This means that the child learns music as well as language. Therefore, Gordon suggests that the family be involved as early as possible in the child's musical development. This theory was confirmed in research by Manturzewska who, through an in-depth biographical analysis of Polish musicians, came to the conclusion that one of the most important factors in the development of musicality is the presence of at least one musical person emotionally connected to the child in their upbringing.

Further, pedagogue Beata Bonna discovered a relationship between the musical activity of preschool children and their mothers' musical education and ability to play an instrument. Interestingly, this relationship was negligible for fathers (Bonna, 2005). This could be the result of an increased attachment between mother and child in infancy and preschool age. In many cases, the mother spends the most time with the child, feeds, nurtures and may sensitize the child to music through joint play, dancing or singing.

Kinga Lewandowska noticed a difference in musical activity between children with music education and children without it. It would seem that this issue is obvious but Lewandowska, however, states that greater musical abilities are conducive to the development of appropriate interests because they are a source of additional satisfaction (Lewandowska, 1978). Therefore, it can be concluded that children brought up in a family with a high musical culture and educated musically will show greater musical activity. The generally understood participation of the child's immediate environment in various types of cultural events can also be distinguished as a favorable factor. This can include the presence of musical instruments at home or listening to music by loved ones. The influence of the family economic situation, which may allow the child to participate in extracurricular artistic activities, may be important.

In sum, during infancy, preschool or early school period, there are many environmental factors that affect the development of a child's musical abilities. This is done by reinforcing the behavior emitted by the child. The importance of acculturation as a factor conducive to the development of a child's musical abilities is also emphasized.

3. Musical abilities and neurophysiology

Various trends have dominated the history of research on musical ability, from the first considerations on the innate nature of musical ability undertaken in the mid-nineteenth century, through to the attempts to systematize research through tests conducted on large samples. Two trends stand out here – the perception of musical talent as a general feature and multi-factor and integrative theories, up to the currently dominant approaches, which can be divided into phenomenological and psychometric, and the "new wave" research of the last 20-30 years, where one can distinguish:

- the current of the psychology of perception and musical psychoacoustics conducted in the convention of cognitive psychology,
- the Musical Meaning research trend, perceiving musical activity in a broader cultural context and drawing on the achievements of psycholinguistics,
- the current of neurobiological and neurophysiological research, largely based on research on brain activity (Kamińska, 2002).

An attempt to divide the phenomenon of musical ability into different components of varying proportions, Maria Manturzewska, has suggested the following:

- musical-specific perceptual abilities, such as pitch hearing, harmonic hearing, melodic memory, sense of rhythm,
- specific musical performance skills,
- musical intelligence (Manturzewska, 2014).

Perceptual abilities include not only the ability to hear a sound as such and the ability to determine its properties (volume, timbre), but also a basic degree of understanding the tonal relationships between sounds. However, the mere ability to distinguish basic musical relationships does not constitute the full musical skills necessary, for example, in the processes of composition and improvisation.

Musical intelligence can be understood in different ways. Currently, there are at least four definitions of it (Majzner, 2019). In this paper, we would like to highlight the definition proposed by Howard Gardner, which includes, among other things, the ability to deeply understand the relationships between sounds, tonal, and rhythmic patterns. From such an approach, it can be concluded that it is the understanding of the relationship between sounds, along with a sense of drama and structure and their impact on the emotional overtones of a piece, that is crucial for skills such as composition and improvisation.

In recent years, the technological possibilities of imaging brain activity have made it possible to draw conclusions regarding the connection of different areas of the brain with various elements of musical activity. From the point of view of neurophysiology, the perception of sound can be summarized as follows: sound otherwise known as cyclical changes in air pressure, goes through the auricles via the ear canal to the eardrum, whose vibrations via the ossicles stimulate the fluid filling the cochlea; the movement of the fluid by means of the organ of corti and ciliary cells is changed into action potentials, which travel along the way of nerve connections – through the auditory nerve and a set of subcortical structures – to the auditory cortex. Pitch perception is possible due to the construction of the cochlea itself, equipped with a series of membranes that, depending on their location in the cochlea, are sensitive only to a narrow range of vibration frequencies. Certain limitations of the structure of the hearing organ affect the range of perceived frequencies (Basiński, 2020). This is the so-called the principle of place, explaining the differentiation of treble, above 4000 Hz (Hudspeth, 2014). In addition, the following are also explanatory: the principle of frequency – perception of pitches up to 100 Hz and the salvo principle – differentiation of the pitch of other tones, the discussion of which would require writing a separate paper.

It can therefore be seen that at the level of structural and functional anatomy there are already a number of points that determine individual differences in the auditory analyzer. This translates into individual differences in terms of auditory perception or musical intelligence, described by the theory of traits (i.e.: maintained in the psychometric trend).

4. Movement of the body to music – rhythmic interpretation

Another element that can be analyzed in terms of individual differences in musical activity are body movements in relation to the perception and performance of music. Frequently, the movement reactions among the listeners are noticeable, depending on the music heard. Motor reactions to heard music are probably known to everyone, even to someone who does not interact with it on a daily basis in a reflective way. A study examining the involuntary movement of the body to music was conducted in 2017 called the "Norwegian Standing Championships." Each of the study participants had a marker placed on top of their head to obtain an average measure of the movement they had traveled. For the first half of the experiment, the participants stood in complete silence, and during the second half they listened to a variety of music. Researchers observed a much larger average amount of movement that the marker traveled during the second half of the experiment (Żelechowska, 2020). Carefully observing the work of your body and the activity of specific muscles can provide feedback on

how much motor effects can affect the interpretation of specific musical structures. At the same time, they can facilitate the expression of playing the instrument or increase the precision of keeping the tempo (Jacomucci, Delaney, 2013). Many unconscious and uncontrolled movements are revealed when playing an instrument. Repeated involuntary movements of the body, unconsciously for a time determined individually for each performer, turn into habits. If these motor automatisms are inconsistent with the rhythmic course of the work or other means of expression, they become a performance problem that is difficult to eliminate. The initial solution then is to become aware of your own motor automatisms during the game. Involuntary and spontaneous body movement is noticeable already in infants and is a universal phenomenon among people, which may indicate its deep biological conditioning. Although thanks to progressive research we are getting to know the condition of the body's functioning from the perception of music, we are not yet able to fully determine the links between music and the movement of our body (Żelechowska, 2020).

In conclusion, involuntary or spontaneous movements to music alone are not of interest to the psychology of individual differences. However, their use in the form of a tool supporting musical performance can be controlled, and therefore subject to the development of the musician-performer. The described motor phenomena concern both the postural muscles and the muscles of the lower and upper limbs.

5. Manual skills

The first studies showing the activity of the brain while playing an instrument showed the activity of the primary motor cortex of the left hemisphere, the cerebellum and areas of the secondary motor cortex, also appropriate for other non-musical manual activities (Czernecka, 2020). Later research also showed increased activity of neurons in the prefrontal cortex correlated with the degree of complexity of the piece being played. The pattern of activity of these areas depends on the level of professionalism of the performer – in beginner musicians it usually covers larger areas, in experienced musicians, smaller but more intense areas are activated. This probably reflects the degree to which, in the course of practice, movements are specialized and their randomness is reduced in favor of precision.

The possibility of changes in the precision of movements is enabled by the phenomenon of neuroplasticity (i.e.: the reorganization of the nervous tissue against the background of the development of the body or as a result of its damage), or through the training of a specific type of activity. Reorganization concerns both structural and functional changes (Rymarczyk, Makowska, Pałka-Szafraniec, 2015). As a result of regular exercise, thanks to the reorganization of the cerebral cortex and the corresponding cortical maps, control over the ring and little fingers (4th and 5th) may become independent, for example. Full independence can occur symmetrically (in both hands) in pianists and accordionists, and asymmetrically in the case of string players (where full independence is required only in the case of the left hand).

When learning and improving playing an instrument, feedback coming from the senses of hearing and sight, as well as from the sense of touch and deep feeling (proprioception) plays a key role in the development of manual skills. Therefore, the activation of motor centers in the brain during musical activities is inextricably linked to the activation of the auditory, visual, and somatosensory cortex (Czernecka, 2020). Procedural memory enables the automation of necessary movements during the game, which is associated with the activity of subcortical structures, including the striatum (Bayley, Frascino, Squire, 2005; Shohamy et al., 2008). Motor memory – another type of long-term memory for which the cerebellum is responsible, cannot be omitted. It is responsible for many motor aspects – repetition of movement sequences without eye control, time organization of individual elements of the sequence, etc. (Baumann et al., 2015).

Information from the sense of touch is the most direct element in the feedback loop between performing an activity and evaluating its effectiveness. It enables both real-time game control and technique

correction, enabling long-term improvement (Rovan and Hayward, 2000). The degree of development of proprioception in individual musicians changes over the course of practice and the development of playing skills. However, its innate level may still affect success when playing a particular instrument, or even influence instrument choice. Studies comparing the level of proprioception in musicians playing different instruments usually focus on the movement of the index fingers (Clark, Harman, & Redding, 2013). However, the innate level of proprioception in the wrist, forearm, and shoulder can have a significant impact on playing instruments in which physical contact is not continuous during playing (e.g.: piano, percussion instruments). Certain elements of playing (e.g.: hitting the keys) require feeling the location of the entire limb in space before it touches the instrument (Smitt & Bird, 2013). On the other hand, playing some stringed instruments (e.g.: guitar) involves constant contact of the hand with the instrument's neck, so in addition to medium-scale proprioceptive sensations (forearm movement), it also provides feedback by feeling the thickness of the instrument's neck in a given position. In the case of brass instruments, there is almost no need to sense the position of the limbs in space, because the fingers can remain in constant contact with the valves, and the other parameters are controlled by the tension of the lip muscles and the breathing apparatus. Thus, the feedback is completely independent of the position of the body in space. In this context, individual differences may predispose to success in playing certain instruments, and almost make it impossible to achieve success in playing others, regardless of generally high, non-motor musical skills.

6. Training – own work

Both professional and amateur musical performance results in characteristic changes in the brain, for example in the area of the primary motor cortex, corpus callosum, cerebellum or the network of connections between the auditory, sensory and motor centers. The transformations taking place are aimed at enabling the performer to perform precise motor control, rhythmic and melodic analysis, planning activities, quick exchange of information and effective cooperation while playing the instrument (Czernecka, 2020).

Among people who deal with musical performance on a daily basis, the quality of their activity in this field is also determined by their memory. Thanks to memory, the musician can fully get to know his playing apparatus and master the performance technique. Memorizing the performed repertoire each time has a direct impact on the interpretation of the work. The musician, instead of focusing on the text, dynamic or articulation markings, can only think about the emotional charge conveyed and the sound depth of the composition. Despite many studies on psychoactive substances that could improve memory processes, scientists have not been able to distinguish any that would have significant effects. Therefore, it can be concluded that "the best method of improving memory is mastering the material well and repeating it" (Kalat, 2020). At the same time, it can be noticed that individual differences in musical activity are not only the result of developmental changes resulting from the influence of the environment. In other words, self-initiated activities aimed at developing musical abilities are also significant.

7. Playing with score and improvisation

Another aspect of skill development within human musical activity may be related to playing as an activity controlled by score. When reading sheet music, in addition to the areas of the brain responsible for the categorization of graphic symbols such as the fusiform gyrus (also active when reading traditional writing) for example, the posterior parietal cortex is also activated, which is part of the dorsal visual pathway, in which there are neurons responsible for the perception of objects in space. This is probably related to the specific nature of the musical notation, where not only the shape of the symbol is important, but also its position in relation to the reference point – the staff (Czernecka, 2020).

Sight reading requires not only visual perception but also short-term memory. Experienced "readers" usually look a few bars ahead of the current fragment, so that in the event of a difficult passage written in the score, they have time to plan their reaction. This requires maintaining a kind of memory "buffer" in which data from the last read measures are stored. The short-term memory used in this process has a limited capacity, although the exact number of items stored in it is difficult to measure. The transfer of information to long-term memory, necessary in the case of performing pieces without musical notation, known as the consolidation process, occurs as a result of the active maintenance of information in short-term memory through the temporary activation of the same neurons forming the reverberation circuit (Kalat, 2020).

In the case of improvisation, the area of the frontal lobe is clearly activated – the inferior frontal gyrus and the anterior part of the cingulate gyrus, which are responsible, among others, for divergent thinking and immersion (Limb & Braun, 2008). At the same time, the activity of the dorsolateral part of the prefrontal cortex, which is responsible for cognitive control – monitoring, regulation and targeting – checking and modifying one's own actions, decreases. According to the postulated concept of two separate neural networks – task-positive and task-negative, whose activity is negatively correlated – the above areas belong to the first of these networks (Czernecka, 2020).

An additional level of complexity arises in the case of the analysis of team improvisation, occurring, for example, in the case of spontaneous jam sessions among musicians who do not know each other. On the one hand, the very fact of practicing improvisation suggests the activation of the task-negative part, (i.e.: the lack of self-critical and monitoring thinking). On the other hand, the social situation – the need to find one's place in the group and develop coherent sounding music together – suggests the need to activate the task-positive system and thinking focused on self-correction. In sum, individual differences in improvisational behavior are reflected in different activity patterns of different neural networks.

Conclusion

This paper presents many areas of individual differences underlying musical activity. This description is not exhaustive. Individual differences in musicality may relate to cognitive functions such as attention processes or cognitive control, there is also the consideration of the differences in the regulation of emotions, stress reactions or temperamental characteristics that determine the effectiveness and scope of activities within the musical activity. In this review we differentiated between different levels of description: On the one hand, it is possible to describe musical activity at the level of neurophysiological indicators, and on the other – psychological ones. In this area, the perspective of trait theory, which deals with individual differences in intelligence, temperament and ability, is useful. This review also discussed the potential impact of environmental factors – family, school, peers, on the development of musical abilities already during human development, including during the prenatal period. The complexity of musical activity itself was also emphasized, which further justifies the wide variance of musical abilities analyzed in terms of individual differences.

Bibliography

Basiński, K. (2020). Podstawy działania ludzkiego systemu słuchowego. (W:) M. Chełkowska-Zacharewicz, J. Kaleńska-Rodzaj (red.), *Psychologia muzyki*. Warszawa: Wydawnictwo Naukowe PWN.

Baumann, O., Borra, R.J., Bower, J.M., Cullen, E., Habas, C., Ivry, R.B., ... Sokolov, A.A. (2015). Consensus paper: The role of the cerebellum in perceptual processes. *Cerebellum*, *14,* 197-220.

Bayley, P.J., Frascino, J.C., Squire, L.R. (2005). Robust habit learning in the absence of awareness and independent of the medial temperal lobe. *Nature, 436*, 550–553.

Bonna, B. (2005). Zdolności muzyczne – ich rozwój i uwarunkowania. Wybrane koncepcje uzdolnienia muzycznego. (W:) W. Limont i J. Cieślikowska (red.), *Wybrane zagadnienia edukacji uczniów zdolnych*. t. 1. Kraków: Oficyna Wydawnicza „Impuls".

Clark, T., Harman, G., Redding, E. (2013). *Pointing to performance ability: Examining hypermobility and proprioception in musicians.* International Symposium on Performance Science: Wiedeń.

Czernecka, K. (2020). Korelaty mózgowe wykonawstwa muzycznego. (W:) M. Chełkowska-Zacharewicz, J. Kaleńska-Rodzaj (red.), *Psychologia muzyki*. Warszawa: Wydawnictwo Naukowe PWN.

Gardner, H. (2002). *Inteligencje wielorakie. Teoria w praktyce*. Poznań: Media Rodzina.

Hudspeth, A.J. (2014). Integrating the active process of hair cells with cochlear function. *Nature Reviews Neuroscience*, *15*, 600–614.

Jacomucci, C., Delaney, K. (2013). *Mastering accordion technique: a new approach to accordion playing based on the Alexander Technique*. Tricase: Youcanprint Self-Publishing.

Kalat, J.W. (2020). *Biologiczne podstawy psychologii*. Warszawa: Wydawnictwo Naukowe PWN.

Kamińska, B. (2002). Zdolności muzyczne w ujęciu psychologii muzyki: ewolucja poglądów. *Studia Psychologica, 3*, 187–195.

Kędziora, S. (2012). Znaczenie muzyki w okresie prenatalnym. (W:) J. Uchyła-Zroski (red.), *Wartości w muzyce. T. 4: Muzyka w środowisku społecznym*. Katowice: Wydawnictwo Uniwersytetu Śląskiego.

Lewandowska, K. (1978). *Rozwój zdolności muzycznych u dzieci w wieku szkolnym*. Warszawa: Wydawnictwa Szkolne i Pedagogiczne.

Limb, Ch.J., Braun, A.R. (2008). Neural substrates of spontaneous musical performance: an fMRI study of jazz improvisation. *PLoS ONE 3*(2): e1679. https://doi.org/10.1371/journal.pone.0001679

Majzner, R. (2019). Inteligencja muzyczna kandydatów na nauczycieli wczesnej edukacji. *Problemy Opiekuńczo-wychowawcze, 2*, 59–67.

Manturzewska, M. (2014). *Psychologiczne wyznaczniki powodzenia w studiach muzycznych*. Warszawa: CEA UMFC.

Manturzewska, M., Kamińska, B. (1990). Rozwój muzyczny człowieka. (w:) M. Manturzewska i H. Kotarska (red.), *Wybrane zagadnienia z psychologii muzyki*. Warszawa: Wydawnictwa Szkolne i Pedagogiczne.

Rovan, J., Hayward, V. (2000). Typology of tactile sounds and their synthesis in gesture-driven computer music performance. (In:) M. Wanderley i M. Battier (eds.), *Trends in gestural control of music*. Paris: Editions IRCAM.

Rymarczyk, K., Makowska, I., Pałka-Szafraniec, K. (2015). Plastyczność dorosłej kory mózgowej. *Aktualności Neurologiczne, 15*(2), 80–87.

Shohamy, D., Myers, C.E., Kalanithi, J., Gluck, M.A. (2008). Basal ganglia and dopamine contributions to probabilistic category learning. *Neuroscience and Behavioral Reviews, 32*, 219–236.

Smitt, M.S., Bird, H.A. (2013). Measuring and enhancing proprioception in musicians and dancers. *Clinical Rheumatology, 32*, 469–473.

Strelau, J., Zawadzki, B. (2016). Psychologia różnic indywidualnych. (W:) J. Strelau, D. Doliński (red.), *Psychologia akademicka. Podręcznik*. Sopot: Gdańskie Wydawnictwo Psychologiczne.

Żelechowska, A. (2020). Poruszeni muzyką – badania nad ruchem ciała w kontekście percepcji muzyki. (W:) M. Chełkowska-Zacharewicz, J. Kaleńska-Rodzaj (red.), *Psychologia muzyki*. Warszawa: Wydawnictwo Naukowe PWN.