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QUANTITATIVE ANALYSIS OF EEG IN INSTRUMENTALISTS DURING MUSIC READING

'Reading is thinking and writing is speech.'[1]

Cognitive perspective of music reading acquisition

Educational neuroscience is an emerging field of science. With the results of neuropedagogical research studies we can explore the hidden processes in the brain related to reading comprehension, attention and attendant difficulties (dyslexia, dyscalculia). In our paper, we would like to introduce the neuroscientific background of upper grader students' music reading skills by means of NeuroSky's MindWave mobile EEG device.

Human musical skills have a long evolutionary history dating back to around 60.000 BC. Music and language abilities enabled the emergence of modern human social and individual cognitive flexibility; both music and language can be regarded as subcomponents of the human communicative toolkit[2].

In table 1, we outline the brain processes which take place during musical and related activities are summarized by Hegedűsné (translated by Buzás)[3] .

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[1] Mihály BABITS, "Irodalmi nevelés." In: *Nyugat,* 1910-3.

[2] Attila SMUTA / Zsuzsa BUZÁS, "Aspects of Kodály's Music Pedagogy." In: *Civic Review, Vol. 13, Special Issue,* 2017.

[3] Tóth Zsuzsa HEGEDŰSNÉ, "A zenei nevelés hatásai." In: *Első lépések a művészetek felé,* ed. by Kinga GYÖNGY, II. Dialóg Campus Kiadó, Budapest 2015.

Left hemisphere	*Right hemisphere*
language functions; grammar, vocabulary, and literal meaning,	the majority of musical skills: tonal, pitch and harmony hearing, absolute hearing
speech comprehension and analysis	visual, spatial perception
temporal perception,	left hand movement
sense of rhythm	abstract thinking, creativity,
right hand movement	understanding of musical communication,
(that is better in marking tempo)	processing emotions,
logical thinking, reasoning	sensitivity to nonverbal effects,
	music perception,
	enjoyment of music,
	association, memorizing melodies,
	ability to recall music

Table 1: Musical and other related activities in the two hemispheres of the brain. (Translated by Buzás[4])

[4] Zsuzsa BUZÁS, "Testing the music reading skills of 10- to 14-year-old students." PhD dissertation. p. 13.

Some biological events related to music and hemispheric specialization can occur only at a critical period[5]. It is of crucial importance to start music learning at a young age. According to Altenmüller and Gruhn[6], the changes in brain activation patterns depend on the personal experiences accumulated over time and the teaching strategies applied.

Music reading is one of the most demanding tasks that involves fast and complex physical activities under auditory feedback together with emotional reactions[7]. The process of music reading related to the seven different fields of music perception skills: pitch, temporal, dynamic, intervallic, melodic, timbre and harmonic.

Pitch processing in the brain

Encoding the pitch of musical scales was one of the first main steps of brain specialization for music. The *Heschl's gyrus* is the center for pitch processing. The right superior temporal sulcus region, the left inferior parietal lobule and the anterior cingulate cortex are also activated by pitch processing. The *planum temporale* is also activated by pitch processing, melody direction, and sound sequences. The discrimination of single pitches is not the prerequisite to the perception of musical units.[8]

[5] BUZÁS, Testing the music reading skills, p. 13.

[6] Eckart ALTENMÜLLER / Wilfried GRUHN, *Music, the brain, and music learning. Mental representation and changing activation patterns through learning,* GIML series vol. 2. Chicago, G.I.A 1997.

[7] BUZÁS, Testing the music reading skills, p. 13.

[8] BUZÁS, Testing the music reading skills, p. 24

Temporal components processing in the brain: rhythm, beat, tempo

The processing of rhythm, tempo and beat have not been explored in similar depth as pitch processing. According to Herholz and Zatorre[9], there are two major neural timing systems: the olivo-cerebellar pathways that mediate duration-based timing, and the striato-thalamo-cortical network that mediates the relative, beat-based timing. The beat activities are in connection with some brain regions; the superior temporal gyrus, premotor cortex, and ventrolateral prefrontal cortex.

Neurocognitive model of music perception

Koelsch and Siebel present the different dimensions of musical perception. Their Neurocognitive model of music perception illustrates the regions where these processes are located in the brain.

Music perception starts with decoding acoustic information that is translated into neural activity in the cochlea and transformed in the auditory brainstem[10]. The transformation of the different acoustic features into perception occurs in the primary auditory cortex. The aural information enters the auditory sensory memory, and the representations of auditory Gestalten[11] are created (Figure 1).

[9] S. HERHOLZ / R. J. ZATORRE, "Musical training as a framework for brain plasticity: behavior, function, and structure." In *Neuron,* 2012-11., p. 486-502.

[10] Gerald LANGNER / Michael OCHSE, "The neural basis of pitch and harmony in the auditory system." In: Musicae Scientiae Special issue 2005-2006, p. 185-208.

[11] T. D. GRIFFITHS / J. D. WARREN, "What is an auditory object?" In: *National Rev. Neuroscience,* 2004-5, p. 887-92.

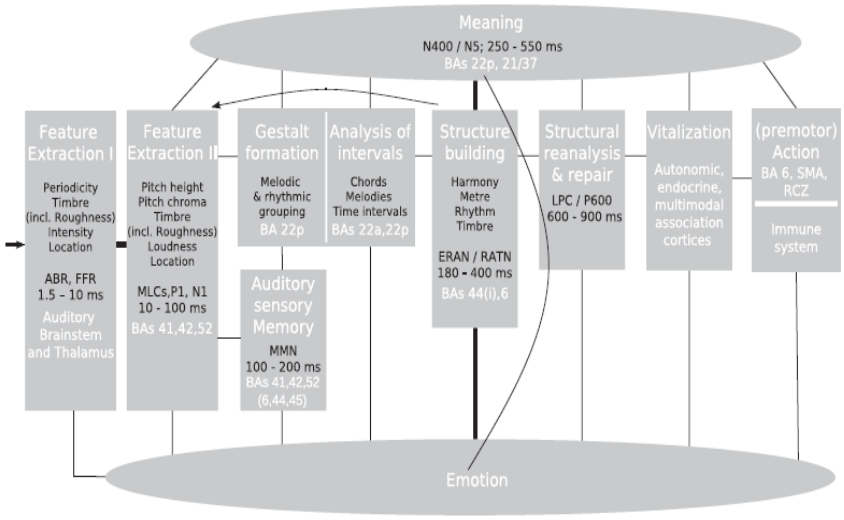

Figure 1 – Neurocognitive model of music perception [12].

ABR, auditory brainstem response; BA, Brodmann area; ERAN, early right anterior negativity; FFR, frequency-following response; LPC, late positive component; MLC, mid-latency component; MMN, mismatch negativity; RATN, right anterior-temporal negativity; RCZ, rostral cingulate zone; SMA, supplementary motor area. Italic font indicates peak latencies of scalp-recorded evoked potentials.

[12] Stefan KOELSCH / Walter A. SIEBEL, "Towards a neural basis of music perception." In: *Trends Cognitive Science,* 2005-9, p. 578–584.

Psychological foundations of music reading acquisition

Written language is a relatively recent cultural invention which came into existence some 5,000 years ago[13] but remained the privilege of a small proportion of the world population until a few hundred years ago. Almost 90% of all children can learn to read alphabetic as well as non-alphabetic scripts and write fluently without obvious problems[14]. The fast and automated recognition of images and symbols are cognitive factors that determine the development of music reading[15].

The basic condition of music reading is the quality of visual and acoustic processing. Music reading involves both the vertical and the horizontal dimensions, so spatial orientation abilities can play a more important role in music reading than in text reading[16]. The ability to understand and enjoy the music primarily seems to depend on how much we know about the patterns in music and how many associations are involved in the emotional content.

When playing music from memory, it is essential to understand the structures of the compositions, and to know the boundaries of musical phrases and motifs and their connection to the piece. When activating the memory, it results in the formulation of expectations based on previous experiences (intervals, harmonies, rhythmic structures).

Schnotz and Molnár summarized the common characteristics of pictorial and verbal information processing in their *Integrated model of text and picture comprehension.* Information is transmitted to working memory through the different sensory channels (verbal and pictorial).

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[13] Keith RAYNER / Alexander POLLATSEK, *The psychology of reading,* Prentice Hall, New York 1989.

[14] BUZÁS, Testing the music reading skills, p. 34.

[15] Valéria CSÉPE, "A nyelv agyi reprezentációjának változásai és zavarai." In: *Magyar Tudomány,* 2005-11, p. 13-36.

[16] BUZÁS, Testing the music reading skills, p. 35.

Comprehension is based on external information and the background knowledge (Figure 2).

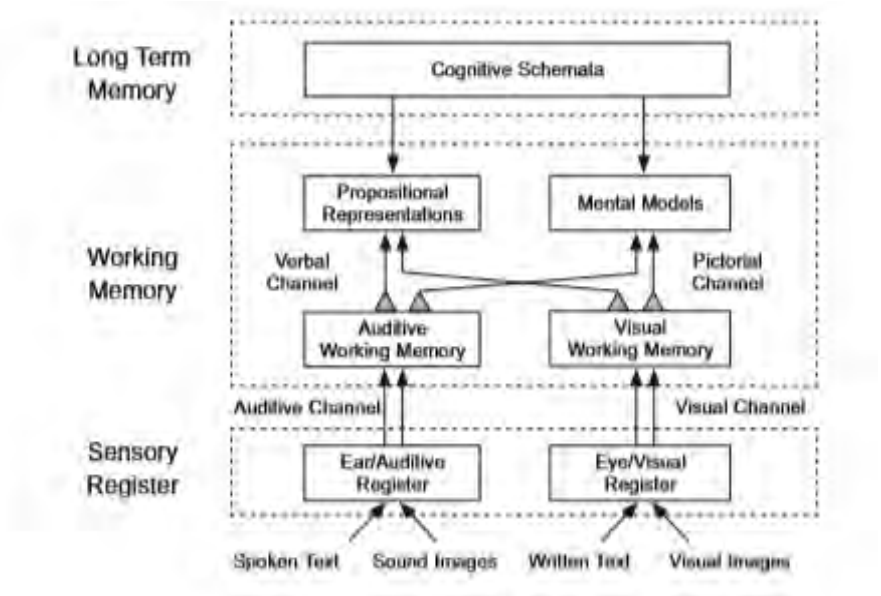

Figure 2 – An integrated model of text and picture comprehension[17].

Music reading involves decoding a vertical dimension (pitch), single elements (notes), elements in combination (chords) and processing timbral features (fullness, brightness, timbral complexity and activity), rhythm and tonal features (pulse, key clarity) through motor-, coordination-, memory- and recognition functions in the brain. Music text reading activates different areas of the brain: the parietal, temporal,

[17] Wolfgang SCHNOTZ / Edit Katalin MOLNÁR, "Az olvasás-szövegértés mérésének társadalmi és kulturális aspektusai." In: *Tartalmi keretek az olvasás diagnosztikus értékeléséhez az első hat évfolyamon*, ed. by Benő CSAPÓ / Valéria CSÉPE, Nemzeti Tankönyvkiadó, Budapest 2012. p. 79-128.

frontal lobes, the fusiform gyrus and the frontal gyrus. These areas are involved in general cognitive processes, as well, like memory- and motor activities, and they are part of the reading network that are located mainly in the left hemisphere (Figure 3).

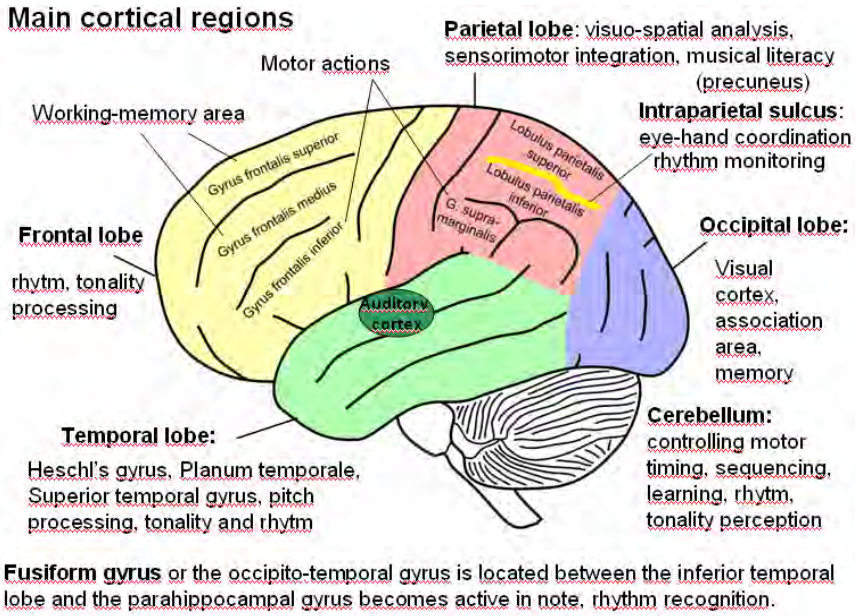

Figure 3 – Neural localization of musical score reading [18]

[18] Valeria MONGELLI et al., "Music and words in the visual cortex: The impact of musical expertise." In: *Cortex*, 2016-86, p. 260-274.