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ONLINE ASSESSMENT OF MUSICAL ABILITIES IN HUNGARIAN PRIMARY SCHOOLS – RESULTS OF FIRST, THIRD AND FIFTH GRADE STUDENTS[1]

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Introduction and Theoretical Framework

Throughout history, music making and singing have had a strong cultural role in every known civilization (Koelsch, 2012). However, although music learning and instruction have had great traditions evolving over the centuries, scientific research on musical ability began less than a century ago and musical testing has an even shorter history. Since nowadays evidence-based educational decisions have growing importance in education policy, standard musical tests are needed to monitor student development and to identify any deficiencies.

There are numerous factors that constrain the valid assessment of musical knowledge using traditional paper-and-pencil tests. This is one of the reasons why only a small body of data is available about the development of musical abilities despite the great significance of the issue. Technology-based assessment is a rapidly developing area, which can be extended to musical abilities and provides new possibilities for diagnostic measurement. Computer-based data collection can enhance the objectivity and validity of the measurement and facilitates application (Csapó, Ainley, Bennett, Latour, & Law, 2012).

For the present study, an online test and a questionnaire were developed to examine musical hearing abilities, their developmental trends, and relationships with other cognitive and social variables among 7- to 12-year-old students. In this paper, we outline the theoretical and historical background of testing musical ability, introduce the measurement instrument, and present the first results of a long-term research project.

Research on Testing Musical Abilities

Although the music curricula of different countries show a high degree of variability, the limited number of music classes is a common phenomenon. Large class sizes and little time usually constrain the possibility of regular evaluation, and they mean a challenge to carrying out diagnostic assessment as well. Thus, technology-based, easy-to-use instruments could support teachers' work effectively. As an added bonus, the use of info-communication technology arouses student interest and helps maintain motivation.

Research efforts in several different contexts demonstrate the importance of musical instruction in primary schools. In contrast to school subjects that are dominated by cognitive goals, the affective effects of music making and singing have primary relevance. Music is a form of communication in close interaction with emotions (Garland & Kuhn, 1995), and singing together and instrumental music making strengthen group cohesion, develop communication skills, cooperation, problem

solving and emphatic skills (Hagen & Bryant, 2003; Gerry, Unrau & Trainor, 2012). As there are increasingly fewer families where active music making and singing is a common form of leisure time entertainment, schools have a more significant role in developing children's musical skills and abilities.

Due to the technological developments of the past decade, the greater part of musical transfer research is from the field of neuropsychology. The representatives of the new research area called neuromusicology examine the brain processes caused by music making or listening. Musical development has a significant effect on functional and structural brain plasticity. Music making stimulates a strong connection between perception and action mediated by sensory, motor, and multimodal integrative regions distributed throughout the brain (Schlaug et al., 2010). These alterations occur with the highest probability in early childhood and at primary school age. In a longitudinal study Hyde et al. (2009) revealed that regular piano lessons in childhood cause significant changes in the anatomy of the auditory and the motor cortex and also in the corpus callosum, which is responsible for interhemispheric communication.

Research on Musical Abilities in Hungary

A scientific approach to musical development has a long tradition in Hungary. Internationally, Sándor Kovács was the first researcher who applied the results and techniques of experimental psychology in the field of musical abilities. Kovács's individual experiments made between 1886 and 1918 focused on the capacity and characteristics of musical memory (Dombi, 1992).

Géza Révész was among the first Hungarian researchers who examined musicality scientifically. His influential book *The Psychology of a Musical Prodigy* (Révész, 1925), focused on the musical development and early gifts of the young piano prodigy, Ervin Nyíregyházi. Subsequently, he also examined musical skills in general. Révész (1946) measured musical abilities in three age groups using eight types of tasks: (1) rhythmic reproduction, (2) pitch reproduction on piano, (3) resolution of intervals and chords played on the piano, (4) interval reproduction from different initial sounds, (5) sense of harmony, (6) vocal reproduction of unknown melodies, (7) reproduction of known melody on the piano and (8) improvisation. In his essential book *Introduction to the Psychology of Music*, he discussed the main aspects of hearing, sound and musical tone; analyzed the fundamental problems of the psychology of music and sound; and gave a detailed demonstration of musical memory and rhythmic sense, in addition to describing the test materials and results. Révész's work was internationally foundational in the development of music psychology.

Endre Szeghy implemented the first large-scale measurement of musical ability in Hungary. Szeghy tested 2,000 primary school children in three Hungarian towns: Szeged, Győr, and Békéstarhos. Similarly to Révész (1957), he also used personal data collection methods and focused on rhythmic and melodic reproduction, vocal interpretation, musical memory, sense of style, and musical empathy skills (Dombi, 1992).

The positive effects of the Kodály teaching system are indisputable. A charismatic music educator, Klára Kokas, drew attention to the importance of transfer effects of musical development and pointed out that music may help to develop cognitive domains without mentally overloading children (Kokas, 1972). Klára Kokas was the first music researcher in Hungary to demonstrate these effects based on scientific methods. At the time of her study, there were more than a hundred pri-

mary schools with a special musical curriculum and numerous musical kindergartens in Hungary. In this comparative study, Kokas (1972) found that focused musical training had a beneficial effect on anthropometric tasks (e.g. lung volume, vital capacity), motoric and balancing skills, skills of observation, and mathematics and grammar performance. Her hypotheses have been corroborated by recent transfer studies indicating that learning music influences various domains including mathematical thinking (e.g. Schmithorst & Holland, 2004), foreign language skills (e.g. Milovanov, Pietila, Tervaniemi & Esquef, 2010) and reading ability (e.g. Janurik, 2008; Loui, Kroog, Zuk, Winner & Schlaug, 2011).

Ilona Barkóczi and Csaba Pléh carried out one of the first longitudinal studies in the field of music psychology. They examined the effects of Kodály pedagogy on the psychological development of primary school children. Their study was carried out between 1969 and 1973 in elementary school classes with and without special musical curricula. The results indicated a positive effect of musical training on the development of creativity and intelligence. While in non-musical classes the correlation between social background and intelligence showed an increasing trend over four years, in musical classes this relationship weakened over time. This study also highlighted the importance and possibilities of musical training in compensating for social disadvantage (Barkóczi & Pléh, 1977).

In the 1980s, József Nagy defined a model of basic musical skills based on the research of Istvánné Erős, Katalin Fodor and István Pethő. The two-dimensional construct is still the most influential conceptualization of musical skills in Hungary. Its two axes are formed by musical content (melody, harmony, rhythm, timbre, dynamic) and musical activities (hearing, communication, reading, writing). A measurement instrument based on this model was developed and a cross-sectional survey was conducted with 840 participants aged between 3 and 23 years (Erős, 1993). This was the first time that musical skills and abilities were explored holistically and at a high level of detail in Hungary.

Two remarkable studies in connection with musical hearing abilities were conducted in the 2000s. Erika Turmezeyné Heller explored the development of musical skills in 7- to 10- year-old children in a longitudinal study between 2004 and 2006 (Turmezeyné, 2009). This and previous studies focused mostly on primary school children but there was no information about the development of musical abilities in early childhood. Márta Janurik and Krisztián Józsa, who developed a test for the kindergarten age group, remedied this. The researchers explored the development of abilities related to musical perception in children aged from 4 to 8 years in a cross-sectional study with 657 participants. The elements and age-related characteristics and structures of musical abilities were examined using a paper-and-pencil test containing eight tasks of musical hearing abilities (melodic discrimination, chord analysis, tempo discrimination, interval discrimination, rhythmic discrimination, timbre hearing, chord discrimination, dynamic hearing) and three tasks of reproduction skills (rhythm reproduction by clapping, vocal interval reproduction, vocal melody reproduction). The authors also explored the relationship between musical performance and other cognitive variables (Janurik & Józsa, 2013).

The technological developments in the past few decades brought about a shift of attention to a new field of music psychology. Since the early 2000s, a number of studies have dealt with the morphological changes in the brain caused by music training (e.g. Shahin, Roberts & Trainor, 2004; Pantev & Herholz, 2011). Among the Hungarian studies the "Visible sounds" program led by Ferenc Honbolygó, Zsuzsanna

Pohl and Valéria Csépe has special significance. The study examined the effects of musical training on phoneme perception, perception of word stress, and perception of musical sequences. The "Visual sounds" program involved a one-year complex musical training program for first year elementary school students. The results showed that the applied training method contributed to the development of hearing accuracy in general (Honbolygó, Pohl, & Csépe, 2010).

Cognitive Perspective of Musical Abilities

Musical memory and perception are fundamental cognitive processes, which can be examined independently of previous training and knowledge. As interest in previous decades focused on the ability models, recent cognitive models of musical processing are more influential in the field of music psychology. These models combine the findings of cognitive neuropsychology and musical ability research.

Peretz and Coltheart developed a modular concept of music processing (2003). In this cognitive-neuropsychological model the processing of auditory input can be realized in three ways: melodic organization, temporal organization and acoustic-to-phonological conversion. The former two are related to musical phenomena and the latter to language processing. Melodic organization is represented by contour, scale and interval. Melody contour shows the direction of pitches, scale is related to tonal functions and the interval shows the frequency distance between notes. Temporal organization is represented by rhythm and metric organization. Rhythm is the grouping of events according to temporal proximity and metric organization can be defined as basic temporal regularity or pulsation.

Assessment of Musical Abilities

Music education has proven to have positive effects on personality, on cognitive domains and also on neural processes. Nevertheless music is not a substantive part of primary school curricula and the current method of assessment is highly subjective and informal. In countries where there is a system of regular monitoring of school performance, subjects not included in this program receive less attention overall. The enhancement of the assessment culture of music education could be a solution to these problems.

Musical testing forms one of the largest single areas of music psychology. From the viewpoint of measured content we can differentiate three main areas: thinking (psychological dimension), application (social and cultural dimension) and discipline (disciplinary dimension) (Csapó, 2004, 2010). We have implemented the measurement of the first, psychological dimension, which measures musical hearing abilities regardless of previous experience or learning.

For the development of the framework for our instrument we drew from the cognitive models of music processing (Peretz & Coltheart, 2003; Koelsch, 2013) and those of musical abilities (Moles, 1969; Erős, 1993; Karma, 2007; Hargreaves, 2012). We developed tasks for temporal organization (rhythm and tempo discrimination), and melodic organization (pitch, harmony and melody discrimination). As our aim was to cover the holistic system of musical parameters, we supplemented the framework with tasks of timbre, dynamics, tonality hearing and visual connection.

Aims of the Study

The measurement of musical hearing abilities is part of a larger project aiming to develop an online diagnostic system for primary schools. In the past few years, the

assessment of mathematics, science and reading were developed and implemented. In 2012 the project was extended to include other cognitive skills and abilities such as the testing of musical hearing.

The aim of the present study was to develop an online measurement instrument that is easy to use and accessible to primary schools in order to help them obtain diagnostic information about the musical abilities of their students. This information allows targeted developmental work even in the case of large class sizes. Obtaining reliable data about musical development is especially important during the first school years when these abilities develop rapidly. In this period, even a minor intervention could be effective.

The objectives of the present study are to explore the potentials of technology-based assessment of musical abilities and to outline the developmental trends of the examined musical abilities by comparing the achievements of several age groups and schools with special musical and regular curricula. The comparison of the achievements of melodic and temporal abilities allows examining the effects of media. Based on the theory of media effects, an acceleration process has begun in the field of temporal musical abilities due to the almost continuous musical inputs which surround children in the urban environment and also at home (Shuter-Dyson, 1993).

Methods

Participants

The participants of the study were first, third, and fifth grade primary school students selected from schools in Csongrád County in the southeastern region of Hungary. The sample included students from a primary school with a special musical curriculum and from non-music primary schools. The music curricula of music schools in Hungary are based on the principles of Zoltán Kodály and Jenő Ádám, students have more music classes a week than in regular elementary schools, and are taught by specialist music teachers. The music classes following the Kodály pedagogy are basically vocal centered, and choral singing has a major role. Although the number of music schools showed a growing trend during the second part of the 20th century—50 music primary schools were operating in Hungary in 1959, with as many as 120 by 1969 and later this number reached more than 200 (Szabó, 1989; Solymosi Tari, 2002)—presently there are approximately twenty music primary schools and a further twenty primary schools with special music classes.

Our sample consists of 155 students from a music primary school and 498 students from non-music schools. In the chosen music primary schools, students had four music classes a week while students in the non-music schools had just one. The students in the two groups were matched for age, gender and parents' education to allow cross-group comparisons.

Table 1
Samples of the study

Grade	Music school	General school	Σ
1	57	162	219
3	54	153	207
5	44	183	227
Σ	155	498	653

Instruments

For each of the musical hearing abilities discussed above, we used discrimination tasks to test cognitive operations related to musical phenomena. Instrumental artists of the National Theatre and the Symphonic Orchestra of Szeged performed the musical stimuli. The test consisted of closed questions, 81 items in total. The items of the test had several innovative features impossible to implement in paper-and-pencil tests.

Temporal organization

Rhythmic hearing tasks are based on the ability to differentiate and memorize temporal patterns. Stimuli played on bongo drums (a non melodic percussion instrument) were used to measure whether students could recognize small differences between two rhythmic patterns.

For the measurement of tempo hearing, we developed tasks containing the same melody twice. The two melodies of a pair could be in the same tempo, or there could be a tempo difference between them. Students had to make a decision whether they were the same or different and, if different, which one was faster.

Dynamics can be defined as the volume change during a given time period. As the time component is crucial in the identification of dynamic characteristics, we discuss the task type here. The task was constructed without using special musical terms, thus students had to identify the volume characteristics of different musical excerpts (strengthened / faded / stayed the same).

Melodic organization

Pitch discrimination tasks contained two musical notes played one after the other. Students had to decide which note was higher. Elementary school student performance with the pitch discrimination task in a diatonic scale is highly informative and shows high explanatory power. The recognition of pitch relationships is the basis of clear intonation as well.

Harmonic discrimination tasks examined how subjects processed the relationship between simultaneously sounding pitches. As the basis of polyphonic hearing and interpretation, the perception of harmonies requires multimodal musical thinking.

The melodic discrimination tasks, similarly to rhythmic discrimination, assessed how students could memorize, group and compare musical excerpts. In these items two melodies were heard one after the other, which could be the same or in which there could be a small difference between them. Students had to decide whether the two melodies were the same or not.

Timbre is a qualitative component of music. Its perception involves the processing of the sound spectrum and the envelope. These test items used polyphonic music excerpts played on different instruments. To avoid knowledge-related issues, the same melody was heard twice and subjects had to decide whether the instruments playing the melody were the same or not.

Tonality refers to hierarchical connections between pitches of a melody. As participants were not familiar with theoretical music terms, we examined the sense of tonality using short melodies in which students had to make a decision whether they were complete or not. The last note of the melodic contour was either dominant or tonic, which are the basic building blocks of melodies in European music (Benjamin, Horvit & Nelson, 2008).

Visual connection

The ability to perceive the connection between the visual and the auditory modality determines the development of music reading and writing. In the tasks measuring this ability, participants had to choose one of four pictures of schematic melodic contour lines that corresponded to the melodic contour being heard.

Background questionnaire

The musical test was accompanied by a brief questionnaire asking students about the testing itself, their school results, attitudes, home environment, music related habits, and the availability of musical instruments.

Procedures

The test was administered through the eDia online assessment platform, which was developed to deliver diagnostic tests. Students completed the tasks in their own schools in classrooms equipped with computers using the operating system and browser originally installed on the computers.

Students had one school period (about 40 minutes) to work on the test and background questionnaire, which proved to be enough time to go through all items. Students read the instructions on screen and could also listen to a voice recording of the instructions if they liked (and as many times as they wanted to). They received musical audio stimuli through headsets and heard each music stimulus just once during the testing. The students controlled their own progress to the next task. There was no time limit for the individual tasks, but students were not allowed to return to the previous items.

This procedure was made possible by the online testing method. In the case of paper-and-pencil tests, all of the subjects hear the musical stimuli simultaneously, whether they are ready or not, and whether they have understood the instructions or not. Online testing provides an opportunity to start the music stimuli when students are fully prepared to listen to them, that is, everybody can answer the questions at their own pace. Another main advantage of the online measurement tool is quite evident but still of basic importance: the volume can be changed according to individual needs.

Results

The test consisted of alternative and multiple-choice closed questions. Each item was worth one point with maximum possible score of 81. Results and answers of the background questionnaire were imported from the eDia platform for statistical analyses.

Differences Between the Age Groups

The test proved to be reliable; the coefficient of internal consistency for the entire unified sample was Cronbach's a = .917 (.843, .877, and .924 for the 1st, 2nd and 3rd grade samples respectively). The results indicate that the difficulty of the test fit the ability range of students. Even the youngest students performed fairly well on the test, and no ceiling effect was experienced even in the oldest group from the music school.

Table 2
Test performance by school grade (mean and standard deviation)

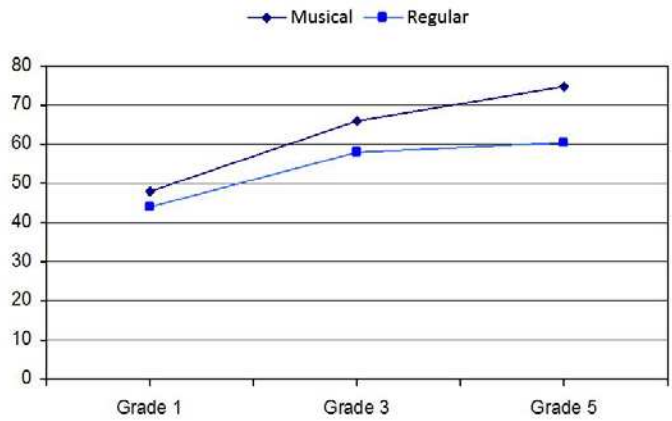
Grade	Test performance (%)	
	Mean	Std. Dev.
1	43.5	14.5
3	57.8	14.6
5	62.9	15.8

An independent samples t test was conducted to compare the results of different age groups. There was a significant difference between Grade 1 and Grade 3 ($t=10.2$, $p<.001$) and between Grade 3 and Grade 5 ($t=3.5$, $p=.001$). The age group results show that musical abilities develop most dynamically during the first school years.

Differences Between Music and Regular Primary Schools

No significant difference was found between the test results of first grade students but in later school years the difference between the two groups shows an increasing trend. Although the development of music school students is unquestionable during the examined school years, no significant difference was found between the third and fifth graders performance in the subsample of primary schools without special musical training (see Figure 1).

Figure 1
Performance differences between the age groups in schools with regular and special music curricula



We used independent t tests to identify differences between subsamples in the various main musical abilities across all grades. The results show that temporal abilities (rhythm, tempo) and timbre hearing evolve similarly in the two groups, while melodic abilities (melody, harmony, pitch) and visual connection show significant differences ($p<.01$) and the performance of the two groups is also significantly different in the case of dynamic and tonality hearing ($p<.05$).

We also individually examined performance on the musical subtests in every grade. We found that in first grade only the visual connection task shows a significant dif-

ference ($p<.05$) between musical and non-musical students. For third grade we found significant differences not only in visual connection ($p<.01$) but also in the case of melody ($p<.01$), pitch ($p<.01$) and harmony ($p<.05$) hearing tasks. The most significant differences were found in fifth grade. At this age level almost every subtest shows a difference (melody, pitch, harmony, visual connection: $p<.01$; rhythm, tonality, timbre: $p<.05$), the only exceptions being dynamic hearing and tempo discrimination.

These results confirm the media-effect theory, that due to the frequent inputs of popular music children's tempo and rhythmic abilities develop more rapidly than their melodic and harmonic skills. Only visual connection performance shows significant differences in every grade, which is the most complex task of the test and requires melodic hearing and an established connection between audio and visual modalities.

Relationships Between Student Performance and the Background Variables

Examining the background variables we found that neither the performance of the music school subsample, nor that of the general school subsample show a correlation with gender or parents' education.

No significant correlation was found between students' estimated and actual performance or their judgment of the test difficulty. However, the interestingness of the test and the test performance shows a modest ($r=.11$, $p<.01$) correlation.

In the questionnaire, student school results were represented by the summative marks they received at school. As these school marks are more characteristic of the achievements of older students, we discuss here the correlations between school marks and the musical test results for the fifth graders only. For students of the music primary school, there was a strong positive correlation between music marks and test performance ($r=.736$ $p<.001$) but we did not find a significant relationship between these variables in the general primary school group. The only school subject that positively correlates with test performance in both subsamples is grammar. The value of the correlation coefficient is .570 ($p<.001$) for the music school and .303 ($p<.05$) for the general primary schools. We found a correlation with mathematics marks only in the general schools' subsample at .365 ($p<.05$). However the music-school subsample's test results show a strong positive correlation with most cognitive variables: with the mean of all school marks ($r=.693$, $p<.001$), with the marks of second language ($r=.434$, $p<.05$), science ($r=.481$, $p<.001$) and visual art ($r=.405$, $p<.05$).

As for the school-subject related attitudes, lower correlations were found than in the case of the cognitive variables. Performance on the musical ability test correlated with attitudes towards school music classes only in the music school subsample at $r=.434$ ($p<.005$).

Discussion

General Conclusions

The results indicate that the online test of musical hearing abilities is accessible in average school settings; as expected, it proved to be an easy to use instrument and the majority of students found the test interesting. The difficulty level was appropriate for the chosen age groups.

The comparison of the different grades indicates rapid development during the first school years. In line with Kodály's pedagogical view, these results highlight the importance of early childhood music education. Early childhood is an especially sensitive period when musical abilities develop the most intensively. The sooner we start music education the better (Csépe, 2013). Focused musical training at school can enhance the development of musical abilities not only in the first school years but also in older age groups.

Our results confirm the hypothesis discussed by Silva & Haase (2013) that melodic and temporal structures are processed independently. The findings of the study support the theory of media effect. Hearing music almost continuously in the urban environment and also at home leads to the result that certain musical abilities develop faster at a young age. These musical inputs are mostly from popular genres and their main characteristics are continuous tempo and well-defined rhythmic structure. Due to these phenomena an acceleration process has begun in the field of temporal musical abilities, like rhythm and tempo hearing. On the other hand melodic and harmonic skills do not follow this developmental trend. However, the Kodály teaching system is basically melody-centered and this could be the reason why music primary school students achieved better performance on melodic tasks.

Visual connection was the only task in which we found significant differences in every age group. This task examines the basic ability of music reading and writing, namely the relationship between the acoustic input and visual signs. Because music reading and notation have an important role in music school curricula as early as in the first few years, the performance of their students was significantly better than that of regular primary school students. Since knowing and applying musical symbols has a positive effect on other cognitive processes and has a holistic transfer effect, the fostering of these skills would be important at the early stages of primary school education.

Our results confirm the findings of Barkóczi and Pléh (1977) that musical achievement is independent of socio-economic background variables. In our study, we have not found correlations between the schooling of parents and test performance. These findings highlight the importance of musical training as a way of compensating for cultural disadvantages caused by social exclusion. The results also indicate that music education can be one means of improving disadvantaged students' attitudes towards schooling by involving them in successful learning activities.

A significant relationship between the music marks given by teachers and the scores on the musical ability test was found only in the subsample of music-school students. This indicates that teachers in the non-music schools may have an inaccurate picture of their students' abilities. Also, attitudes towards music classes show a correlation with test results only in the case of music primary school students.

A low correlation was found between students' subjective estimation of their own performance and their actual performance on the test, indicating that students do not have a realistic musical self-concept. Systematic objective assessment of musical abilities may contribute to solving these problems and may help students to build a more realistic musical self-concept. The test score correlations with subjects like grammar, mathematics, science, visual arts and second language draw attention to the transfer effects of music, which need further research.

Further Prospects for Computer-Based Assessment of Musical Abilities

Further research is required to identify the developmental characteristics after the fifth school grade. It should be studied whether development continues beyond this age or measured abilities stagnate without focused music training.

The structure and relationships of the examined musical hearing abilities should be further elaborated. As computerized testing allows more differentiated assessments, the theoretical frameworks should be adapted to these broader possibilities. In order to obtain information about the later developmental process, the extension of the age range is needed, and the assessment instruments should be enriched with more difficult items to avoid ceiling effects in the best achieving music-school age groups. The online platform provides an opportunity for examining the relationship between the development of reading skills, mathematical thinking and musical abilities. And finally, adapting the measurement tool to preschool children could open a new research field in technology-based musical ability testing.

This study has demonstrated that online assessment can be made accessible anywhere and that low cost easy-to-use tests may help to monitor the development of musical abilities. The results presented here and the circumstances of the declining number of music primary schools in Hungary bring to mind the ever-topical quote by Kodály: "Let music belong to everyone!"

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