

THE EFFECTS OF VISUAL ADAPTATIONS OF STANDARD MUSIC NOTATION ON A GIRL WITH SPECIFIC LEARNING DISABILITIES PLAYING THE CIMBALOM

VLIV VIZUÁLNÍ ADAPTACE STANDARDNÍ NOTACE U DÍVKY SE SPECIFICKÝMI PORUCHAMI UČENÍ PŘI HŘE NA CIMBÁL

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Abstrakt:

Využití vizuálních adaptací standardní notace (SN) u žáků se specifickými poruchami učení (SPU) je tradiční součástí výuky hry na hudební nástroje. Tato oblast hudební výchovy je však nedostatečně prozkoumána a je založena převážně na empirických zkušenostech učitelů. V této případové studii jsme zkoumali vliv barevného pozadí, zvětšených not a barevného kódování paliček při čtení z listu SN u hudebně nadané dívky se SPU hrající na cimbál. Pseudorandomizovaná série testů pro čtení výšky tónu s vizuálními adaptacemi byla použita v několika měřeních po dobu 5 týdnů. To bylo kombinováno s kvalitativním polostrukturovaným rozhovorem provedeným se studentkou a její matkou. Chyby dívky se během testovacích sezení snížily. Přestože mezi testovanými intervencemi byly jen nepatrné rozdíly (max. 2 chyby), celkové zlepšení čtení z listu s SMN mělo na dívku výrazně pozitivní dopad. Intenzivní a cílený trénink SN (včetně vizuálních adaptací) může mít pozitivní dopad na žáky se SLD. Doporučujeme vytvořit testy čtení z listu na základě výšky tónu/rytmu, které umožní maximalizovat účinky intervencí s čtením z listu.

Abstract:

The usage of visual adaptations of standard music notation (SMN) for students with specific learning disabilities (SLD) is a traditional part of musical instrument instruction. However, this area of music education is under-researched and based mostly on the empirical experience of teachers. In this single case study, we explored the effects of coloured backgrounds, enlarged notations and colour coding of mallets on sight-reading SMN of a musically gifted girl with SLD playing the cimbalom. A pseudorandomized series of tests for pitch-reading with visual adaptations was used in multiple measurements for 5 weeks. This was combined with a qualitative semi-structured interview conducted with the student and her mother. The girl's errors decreased during the testing sessions. Although there were only slight differences among the tested interventions (max. 2 errors), the overall improvement of SMN sight-reading had a notably positive impact on the girl. The intensive and targeted training of SMN (including visual adaptations) may have a positive impact on students with SLD. We recommend creating pitch/rhythm sight-reading assessments that will enable to maximize the effects of sight-reading interventions.

Klíčová slova: dyslexie; specifické poruchy učení; notový zápis; hudba; cimbál; zvětšený notový zápis; barevné pozadí.

Key words: dyslexia; specific learning disabilities; notation; music; cimbalom; enlarged notation; coloured background.

1 INTRODUCTION

Arts-based education with a focus on playing a musical instrument is provided in elementary artistic schools (EAS) in the Czech Republic. These schools develop and cultivate the artistic talent of a wide range of interested students who have demonstrated the necessary prerequisites for study and are settings for the identification of exceptionally gifted individuals (Stárek, 2010). In this way, it fulfils an important cultural function in society (Zayas et al., 2024). The current challenge for EAS is the growing number of pupils with special educational needs (SEN), mainly students with specific learning disabilities (SLD). Teachers at EAS are generally not prepared for teaching (focused on special educational strategies) such students and there is a lack of research that could be used to guide the educational practice in this area. Because one of the most important requirements in musical disciplines is the knowledge of standardized musical notations (SMN), we conducted a single case study with the aim to explore the effects of visual adaptations of SMN for a musically gifted girl with learning disability playing the cimbalom.

1.1. Students with specific learning disabilities

Specific learning disabilities are neurodevelopmental conditions that are typically diagnosed in early school-aged children and characterized by persistent impairment in at least one of three major areas: reading, written expression, and/or math (DSM 5, 2013). Among the most frequently diagnosed types of SLD are dyslexia, dysgraphia and dyscalculia.

Dyslexia is a specific learning difficulty associated with reading and writing and presents as challenges with word recognition, spelling, decoding, phonological awareness, as well as the process of automation (Zelinková, 2015).

Dyslexia is often accompanied by other SLD such as dysgraphia or dyscalculia. Dysgraphia, also a specific learning disability in written expression, is defined as "a disorder of writing ability at any stage, including problems with letter formation/legibility, letter spacing, spelling, fine motor coordination, rate of writing, grammar, and composition" (Chung et al., 2020, S46). In a similar way, dyscalculia may be considered as a specific learning condition that affects students' comprehension and manipulation of numerical concepts (Salisa, Meiliasari, 2023).

1.2. Music education for students with specific learning disabilities

Legislatively, education in Czech EAS is anchored in the Framework Educational Program for Elementary Artistic Education (Ministry of Education, Youth and Sports, 2020), which is a basic curricular document defining the conditions for education in music disciplines. A student with SLD who enters education at EAS should be granted educational support according to Decree 27/2016 Coll. on the education of students with SEN and gifted students. These supports may include the development of an individual educational plan, the assignment of a teaching assistant, the accommodation of teaching methods and other interventions (Sedláčková et al., 2022). The education of students with SLD should be implemented with the support of school counselling services. However, the cooperation between counselling centres and EAS is currently not present, not only due to the workload of counselling professionals, but also because they do not have sufficient knowledge of special methods and procedures used in music education (Polínek, 2020; Salvador, Pasiali, 2016). At the same time, the teachers at EAS do not feel prepared to teach students with SEN and miss necessary didactic skills (Kružíková, 2020).

This problem is not unique to the Czech Republic; however, some other European countries provide more systematic support to teach musical instruments (Kantor, Šteffková, 2016). In Germany, there is an association of German music schools (hereinafter VdM), which already in 2014 approved the statement "Music school in transformation - Inclusion as an opportunity." VdM offers further education opportunities for teachers, e.g., in the form of the course "Playing a Musical Instrument for Students with Disabilities in Music Schools" (BLIMBAM), authored by Werner Probst (Probst, Beierlein, 1991). Additionally, there are internationally recognized didactic approaches and materials for music education of students with SEN in English-speaking countries, such as Colour Staff by Hubicki (Hubicki, Miles, 1991).

An important part of the use of musical education methods for students with SEN is the knowledge of unconventional approaches to mastering the sight-reading of musical notation (Kantor et al., in print). Although playing an instrument may be achieved by imitating the teacher and playing from memory (Probst, Beierlein, 1991), these methods have major limitations. Imitation may be suitable before the student has mastered reading

musical notation, for simple melodies and songs. As the difficulty of compositions increases, emphasis is placed on sight-reading of SMN. When the student manages to master sight-reading, they gain independence, the opportunity to return to compositions previously played, the ability to investigate parts of compositions of interest, increased understanding of composition form, etc. Moreover, more demanding compositions are relatively difficult to learn without knowledge of musical notation.

However, SMN sight-reading may be very challenging for students with SLD. They may be specifically challenged by the visual complexity of musical notation, the musical staff is often confusing for them, the lines merge, the notes and other symbols seem to be similar (Solook, 2015). It is described as visual stress characterized by visual discomfort and pattern glare, which can induce headaches (Kriss, Evans, 2005). Visual processing, e.g., the adjustment to focus from far to near or spatial directional awareness, may be distorted (Raviotta, 2017). Also, processing multiple pieces of information simultaneously, such as pitch, length of note, and musical rhythm, may be difficult because of overburdened working memory (Gray et al., 2019). Specific theories such as the Dyslexic Automatization Deficit Hypothesis suggest explanations of these deficits, e.g., disorder in automating arbitrary conventions and associations (Jaarsma et al., 1995). Flach et al. (2014) highlights the more complex and challenging nature of SMN sight-reading compared to usual text.

To overcome these problems, students with SLD may benefit from unconventional music notations (UMN). According to the classification proposed by Kantor et al. (in print), UMN may include:

- Visual adaptations of regular notations such as colored coding of the musical lines Gyarmathy, 2015), colored backgrounds/overlays (Raviotta, 2017), larger font size (Flach et al., 2014), or different font (Parsons, 2015).
- UMN is not based on the use of a musical staff and often uses different types of symbolization to display the pitch and length of notes, e.g., colour coding (Langendonck, 2019), short and long vertical lines representing the length of the tones (Ganschow, 1994), numbers and pictures (Gyarmathy, 2015), pictures or dots indicating the corresponding key on the keyboard when playing chords (Arntzen et al., 2010).

For students with SLD, visual adaptations of regular notations are often recommended (Ganschow, 1994). Notations that are not based on the use of musical staff are recommended for music education for people who have more severe cognitive deficits, e.g., because of autism spectrum disorder, brain injuries, intellectual disability or dementia (Kantor et al., in print).

1.3. Cimbalom education

The cimbalom is a very typical instrument in traditional music of Middle Europe. It is a percussion-stringed musical instrument characterized by its trapezoidal shape and metal strings stretched over a soundboard (Figure 1). The cimbalom is played by striking the strings with mallets. (Gifford, 2001; Johnston, 2010; Herencsár, 2019)



Figure 1. The cimbalom (from the archive of the authors).

Sight-reading of musical notation for the cimbalom is not easy. This is due to the illogical and unsystematic nature of the string system, where the notes in each octave are not stored the same, many strings are divided by frets, sometimes even three times, which means that the musician plays up to three notes on one string. Therefore, it often happens that a semitone is not the closest distance but can be several tens of centimetres away (Droppová, Čečková, 1987). Figure 2 shows semitone steps where the semitone is an adjacent string (f1 – fis1, c2 – cis2), but also semitone steps that are distant across the entire width of the cimbalom (c1 – cis1, d2 – dis2). An example used in educational practice is the diagram developed by the main author, where the student draws the progression of scales directly into the cimbalom string system.

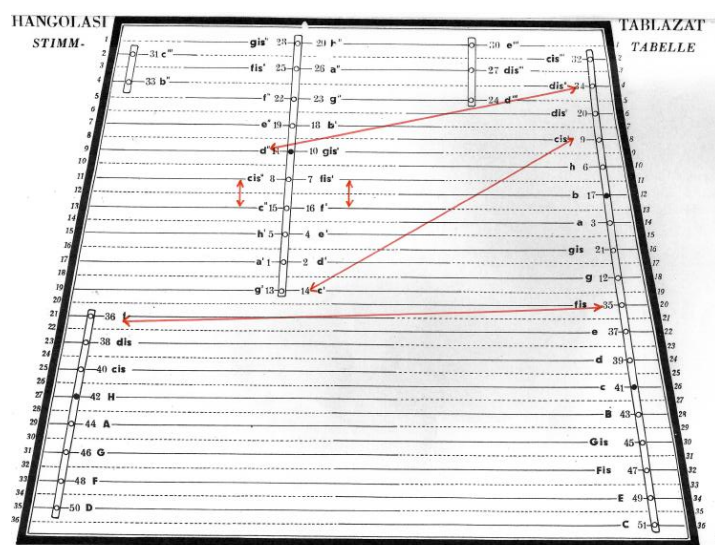


Figure 2. Diagram of tone progressions according to a scale order in the string system of a cimbalom (from the archive of the authors).

The music stand is located at the head of the instrument (Figure 3), which also makes it difficult to develop visual-motor coordination and orientation in musical notation. For this reason, many children choose to learn everything by heart as quickly as possible.



Figure 3. The cimbalom stand (from the archive of the authors).

When playing the cimbalom, two mallets are used that serve as extensions of the hands. The system is like the piano, also a stringed percussion instrument, where the strings are struck by felt hammers, but controlled via a keyboard (i.e., 88 keys = 88 hammers operated by 10 fingers). With cimbaloms, the contact with the instrument and the string is much closer, however, contact with the string is mediated by only two mallets. Just as pianists use fingering to numerically designate fingers, in cimbalom playing the so-called mallet position is used: left hand = 1, right hand = 2. (Johnston, 2010)

Mallet position is another important part of reading notes with adherence to the principles of correct mallet formation, such as the principle of alternating mallets, the principle of playing with one mallet only at the closest distances and, if possible, with one mallet only twice. (Brada, 1982) Students are given a note with their mallet placement written down in the music notation and are encouraged to use the written mallet placement immediately while reading the notes and learning the pieces.

When reading the notes, it is important to be able to read the notes in advance and plan which mallet to play with. The sequence of mallet placements, distant jumps with the mallets, is one of the motor skills that cannot be done without anticipation, i.e., time anticipation and prediction. (Droppová, Čečková, 1987) Most often, instrumentalists use visual anticipation, i.e., when playing from the notes, they anticipate and read the music notation forward, which is strengthened by kinetic anticipation, where the visual perception is passed over by the fingers, or rather the mallets. These two anticipations, visual and kinetic, are also combined with cognitive anticipation, which helps to shape the work as a whole (Sedlák, Váňová, 2013). Students often focus primarily on reading music notation correctly, but they neglect using the correct mallet.

1.4. Justification of the study

The recent scoping review (Kantor et al., in print) mapping the existing UMN for people with SLD/SEN found only rare research studies on the sight-reading of SMN using the visual adaptations. Flach et al. (2014) investigated through the cross-sectional survey the effects of increasing the font size (32%), the same direction of note flags, and coloured lines on note reading in children with/without SLD and children with reading difficulties. However, only font enlargement and the use of the same direction of note flags resulted in fewer errors in note reading. Solis (2010) found a significant effect of using coloured background/overlays in pitch and rhythm reading in three cases of students with dyslexia. Other studies focused on various cognitive disorders and neurotypical population. As an example, Rogers et al. (1991) researched the use of color-coded notation in a general population as well as students with intellectual disability and found a positive effect of coloured notation on sight-reading and

note naming. Langendonck (2019) found a beneficial effect of different coloured background on recognition of musical notes in a child with autism spectrum disorder.

Given the paucity of the research on UMN in people with SLD, we explored the effects of visual adaptations of SMN on a case of a gifted student with SLD playing the cimbalom.

Research question: What are the effects of visual adaptations (enlarged music notation, coloured background and color-coded mallet) compared to SMN on pitch-reading in a girl with SLD?

2 METHODS

This single-case study was conducted according to the principles of the Helsinki declaration. The study participant and her legal representatives were informed about the purpose of the study and signed the informed consent to be included in the study. They were also provided with information that they could withdraw from the study at any time without giving any reason. Moreover, they wished to use the real name of the girl for the purpose of publication of this study.

Inclusion criteria:

- The student should have dyslexia or another learning disability that affects the acquisition of SMN.
- The student should be learning to play an instrument at an EAS.
- The student should be motivated to cooperate and voluntarily participate in the implementation of the study.

2.1 Case description

The case was selected from the practice of the main author of the article, who teaches at the Elementary Artistic School in Valachia region, Czech Republic (cimbalom playing and theoretical music subject's). The school strives for an individualized approach to children and the goal of finding a positive and joyful way to introduce children to the world of the arts. The selection of a suitable case for this study took place in the cimbalom playing class, where the case of a student named Naira with SLD was selected.

At the time of the study, Naira was an 11-year-old girl attending the 4th grade of EAS once a week. She was diagnosed with dyslexia, a mild form of dysgraphia. She demonstrated a slow pace of reading and writing, and weak graphomotor skills. According to the system of educational support provided to pupils with SEN in the Czech Republic, she was officially classified as a student with SEN, however she did not qualify for an individual educational plan or the provision of a teaching assistant. Naira is a calm, quiet girl, cheerful, smiling, and very perceptive, even if her attention is easily disturbed by any distracting stimulus.

Before she started to be educated by the main author of this article (September 2023) Naira had two cimbalom teachers. In September 2023, she did not have the basics of playing the cimbalom experienced and fixed, and she was tasked with playing pieces beyond her technical capabilities. She had learned pieces with technical imperfection, and her desire to play the cimbalom decreased. The music notation provided by the previous teachers was often difficult to read, already copied several times with notes and comments from other teachers. This made it very difficult for her, as a student with dyslexia, to navigate the music notation. She had never experienced playing according to the UMN.

Specific problems that Naira experienced when reading the SMN included confusion with the placement of spaces, frequent confusion of notes c^2 and e^2 , and difficulty distinguishing between interval steps of a second and a third. On the cimbalom, Naira had difficulty visually following the notation and the string system of the cimbalom at the same time. As soon as her eyes were taken away from the notation to check the mallet and its placement over the correct string, she became lost in the notation.

She also had difficulty distinguishing between her right and left hands. She took longer to process instructions on which hand to play.

Naira had also attention challenges, which were manifested by momentary lapses of attention and by being easily distracted by other stimuli. When Naira played a piece for the first time on a given day, it was often her best performance. As soon as the piece began to be discussed in parts, including revisiting errors and playing the piece with the teacher, her performance in reading music deteriorated. A common intervention by the teacher in these cases was to include a short break.

Naira was extremely motivated to learn to play the cimbalom, which was also proven by the fact that she commuted 45 km to EAS. She received great support from her mother, a kindergarten teacher, who is also a music enthusiast and plays musical instruments herself as an amateur.

2.2. Types of visual adaptations of musical notation

In this case study, several types of visual adaptations of SMN were used (Tab. 1), the effect of which was compared with reading according to SMN (7 mm).

Tab. 1 Description of interventions applied.

Number of the intervention	Type of visual adaptation
Intervention 1	SMN, staff size 7 mm (control condition)
Intervention 2	Without adjustments, enlarged staff 10 mm
Intervention 3	Color-coded mallets, staff size 7 mm
Intervention 4	Colored background, staff size 7 mm
Intervention 5	Colored background, color-coded mallets, staff size 10 mm

The hypotheses for selecting these visual adaptations were as follows:

- Enlargement of the staff (from 7 mm to 10 mm) – enlargement of the staff is reported as one of the effective strategies for improving music reading in students with SLD (Flach et al., 2014). In addition, the music stand on the cimbalom is at a greater distance, so we assumed that enlarging the SMN may make it easier for the student to read it.
- Printing the notation on a colored background – using a colored background is another effective strategy according to previous studies (Solis, 2010). It is recommended that students choose a specific color for the background. Pink, yellow, green and blue backgrounds were prepared for Naira, and she chose to use blue. When choosing the background, the student considered the popularity of the color the most.
- Color coding for mallets – the student had trouble distinguishing between the right and left mallet, which complicated the use of the correct mallet placement. We assumed that the student could be helped to distinguish and mark the mallet by the colored marking of the mallet (Figure 4) and similarly by the color-coding of the notes in the musical notation.



Figure 4. Color-coded mallets (from the archive of the authors).

2.3. Outcome measures

The main outcome of this case study was to monitor the number of errors for pitch-reading, using a series of self-created tests, while practicing the composition Minuet in C major by Alexander Reinagl, and an interview with the student and her mother.

2.3.1 Creation of original tests

Due to the lack of suitable standardized tests for testing pitch-reading for cimbalom players, it was necessary to create testing material for this case study. We needed to prepare multiple test variants of similar difficulty so that the result would not be biased by repeated measurements of the same task during the study. At the same time, this material had to be of an appropriate level of difficulty level to Naira's current abilities.

In order to prepare such materials, the first author conducted a series of tests, the result of which was the creation of an original set of exercises (Appendix A). These exercises were created in the program Sibelius, where the staff can be enlarged as needed, notes can be marked in color, the staves can be moved apart, etc. A total of five exercises were created with a range of 16 measures, in whole note values, at a tempo of $M = 90$, in the tonal range c^1 – g^2 , with the note c^1 to start and finish with. The same notes were used in different combinations, and eight measures on one line were kept. The exercises were printed on A4 (landscape) format so that the exercises fit 8 measures on one line, each exercise separately on a page. Each exercise was processed in five interventions (Table 1), the order of the interventions changed with each testing. For these purposes, a pseudorandomization scheme was used, where a numerical code is used in the following tables to indicate the order of the interventions and the serial number of the testing.

2.3.2. Testing on the composition Minuet in C major by Alexander Reinagl

In addition to the artificially constructed tests, we decided to monitor the development of note reading on a real composition. For this purpose, Minuet C major by Alexander Reinagl was selected, which met the criteria for individual exercises – it reflected the created exercises in terms of both scope and difficulty in reading notes (range from c^1 to g^2 , eight and eight number of bars, containing only quarter and eighth note values). Minuet C major is in a classical form, consisting of two parts A and B, each part is eight measures long. The notation was transcribed by the author in the Sibelius program, a 10 mm staff, without mallet signs, printed in black color on a white paper.

The composition was applied as a pre-test and post-test outcome measure to determine the progress of sight-reading from SMN. During both pre-test and post-test conditions the student was given two tasks:

- The first task (1) was to reproduce the pitches of the notes while reading the music notation, without pedaling or rhythm; the student was not instructed on the mallet position.
- The second task (2) consisted of reproducing both the pitches of the notes and the rhythmic performance according to the music notation.

The tempo of the piece was not specified; it was left to the student.

2.3.3. Interview with the student and her mother

The testing was supplemented by a semi-structured interview with the student and her mother, which took place after the testing was completed. The interview (approximately 30 minutes) was conducted with both study participants at the same time in the school classroom where the testing was also taking place.

Areas of the interview:

- Naira's motivation for choosing the instrument and her early experiences playing.
- Experience with reading music and with different types of interventions.
- Changes in reading music that occurred during the study and their connection to Naira's current experience to play the cimbalom and to progress in other (non-musical) areas.

2.4. Experiment Procedure

The testing took place during the regular cimbalom lessons, for 7 weeks every Friday from 3:15 PM to 4:15 PM between March 15 and April 24, 2024 (due to the holidays between March 15 and April 5, only 5 meetings took place). The lesson schedule is shown in Tab. 2. The first test intervention was presented to the student after the initial play, approximately 5 minutes later. Between each subsequent testing intervention, there was a break in the form of regular practice of the assigned pieces so that the student did not memorize the sequence of notes in the exercise.

The testing took place in a quiet environment of the cimbalom class, undisturbed by the surroundings. The mother, who attends the cimbalom lessons, was not present at the time of testing. All tests were conducted only once and were audio recorded. The metronome was present on all the recordings to ensure the same tempo of playing.

Tab. 2 The scheme of the lessons.

Time	Scheme of the lessons
15.15 – 15.20	Musical warm up
15.20 – 15.25	Test number 1
15.25 – 15.35	Scale exercise
15.35 – 15.40	Test number 2
15.40 – 15.50	Chords
15.50 – 15.55	Test number 3
15.55 – 16.05	Technical exercise
16.05 – 16.10	Test number 4
16.10 – 16.20	Composition
16.20 – 16.25	Test number 5

Interventions with individual types of visual adaptations (Tab. 2) were pseudorandomized according to the testing schedule (Tab. 3).

Tab. 3 Testing schedule.

Date of testing	Order of tested interventions
March 15 2024	1-2-3-4-5
April 5 2024	2-3-4-5-1
April 12 2024	3-4-5-1-2
April 19 2024	4-5-1-2-3
April 26 2024	5-1-2-3-4

2.5. Data analysis

The evaluation of the testing data was carried out using descriptive statistics, with the number of errors for each type of intervention and the total number of errors for all interventions being counted for each session. In addition, the types of errors that the student made were narratively presented, which could help to understand her problems with reading notation.

In the testing using the Minuet in C major, errors were counted only for the pitches of the notes, although during the second pre-test and post-test Naira was instructed to play the piece according to the

rhythmic values. However, these parameters (rhythmic values, tempo, tone quality) were only narratively described, as they were not the subject of the previous testing.

The interview with Naira and her mother was analyzed through content analysis (Hsieh & Shannon, 2005), primarily looking for statements that could provide a better interpretation of the quantitative data, understand the student's experience with visual adaptations.

3 RESULTS

The description of the study findings is divided here according to the individual data sources into results from the tests created by the authors, results from testing using the Minuet in C major and results obtained from an interview with Naira and her mother.

3.1. Findings from original tests (created by the authors)

The students' performance improved significantly during testing (Tab. 4). This improvement is present for all types of visual adaptations, including playing according to SMN, which served as a control condition. The differences between the individual interventions within each measurement do not exceed 2 errors. The most common error in various interventions was most often the exchange of notes between the notation lines.

The colored coding of the mallet rather complicated the student's reading of notes, in the sense of a subsequent higher error rate. However, it was caused by the lack of instructions related to mallet position given before each testing session. If the mallet position was not marked, she started to play mostly with one mallet (especially the more difficult passages). Playing the same piece with two mallets brought an additional challenge to the reading of notes, which resulted in more errors.

Tab. 4 Findings from original tests material testing.

Interventions	March 15	April 5	April 12	April 19	April 26	Total
Intervention 1	2	4	0	1	0	7
Intervention 2	3	2	0	0	1	6
Intervention 3	3	2	1	1	1	8
Intervention 4	2	2	2	0	1	7
Intervention 5	1	3	2	2	1	9
Total	11	13	5	4	4	37

The analysis of the types of errors in the individual sessions was important for interpreting the student's performance.

3.1.1. Session 1

Errors occurred when reading notes between notation lines, mainly in the double-barred octave. A common error in all interventions was the confusion of the note e^2 with c^2 (bar 6). When playing with the standard and enlarged staff (Interventions 1 and 2), the student also confused the note g^2 with e^2 (bar 5) and in Intervention 2 she confused the note a^1 with f^1 (bar 12).

The color-coded mallet (Intervention 3) helped her to orient herself in the string system, she was able to plan her mallet placement better. However, she again confused g^2 with e^2 (bar 5) and e^2 with c^2 (bar 6) and in bar 12 she confused a^1 with c^2 . Similar errors were also made in intervention 4. The best result (1 error) was for intervention 5. See Tab. 5.

Tab. 5 Details related to session 1.

	Intervention	Size of notation	Other adaptations
1_1	1	7 mm	No adaptations
1_2	2	10 mm	No adaptations
1_3	3	7 mm	Colored coding of mallets
1_4	4	7 mm	Colored background
1_5	5	10 mm	Colored background + colored coding of mallets

3.1.2. Session 2

The notes used for session 2 were the same as in session 1 but in reversed mode. In all interventions, the student made the same mistake. In the ascending row between bars 3 and 4, she added the note f^1 , thereby adding a bar, or replacing the following note. The same mistake appeared again, replacing e^2 with c^2 and g^2 with e^2 . During this test, it became obvious that the student had problems with orienting herself in spaces between lines, regardless of the size of the staff.

In intervention 1, she replaced g^1 with f^1 (bar 4) and played a^1 twice instead of g^1 (adding a bar). In bar 9, she accidentally played cis^2 instead of c^2 (in this case, it was not a note reading error, but an error in orientation in the string system, since cis^2 is on the next string). This typo threw her off, she skipped measure 12 and continued until measure 13. In intervention 2 and intervention 3, she added the rising row of notes with the note f^1 . (Measure 4). In intervention 3, she also replaced the note f^1 with d^1 (measure 7). In intervention 4, she also replaced c^2 with e^2 (measure 9). In the fifth intervention, she also replaced the note e^1 with g^1 (measure 6) and f^1 with a^1 (measure 7). See Tab. 6.

Tab. 6 Details related to session 2.

	Intervention	Size of notation	Other adaptations
2_1	2	10 mm	No adaptations
2_2	3	7 mm	Colored coding of mallets
2_3	4	7 mm	Colored background
2_4	5	10 mm	Colored background + colored coding of mallets
2_5	1	7 mm	No adaptations

3.1.3. Session 3

In this session, the bars (except for the first and last bar) were created by exchanging the order of bars from the previous exercise in pairs (bars 2 and 3, 4 and 6, etc.). In this exercise, the notes appeared in larger interval distances, not in ascending or descending clusters of notes. This unexpectedly suited the student better. The most frequent errors were again evident in the ascending melody $e^1 - a^1$ (bar 10-13), when the student exchanged the notes f^1 for d^1 (bar 11) and a^1 for c^2 (bar 13). In intervention 3 and similarly in intervention 5, she again played cis^2 instead of the note c^2 (bar 5). In measure 11, she got lost in the notation, so she extended the note lengths for a moment. In intervention 4, she replaced the note f^1 with d^1 (bar 11) and the note a^1 with c^2 (bar 13).

In this session, it was also clear the role of color coding the mallet position had for the student. She played interventions 1 and 2 without error in this session, only because the mallet position was not coded in these interventions. Therefore, the student did not alternate mallets because it was easier for her to practice correctly with only one mallet or with the second mallet, where she succeeded. When the mallet position was coded with color coding, she was able to alternate mallets much better. See Tab. 7.

Tab. 7 Details related to session 3.

	Intervention	Size of notation	Other adaptations
3_1	3	7 mm	Colored coding of mallets
3_2	4	7 mm	Colored background
3_3	5	10 mm	Colored background + colored coding of mallets
3_4	1	7 mm	No adaptations
3_5	2	10 mm	No adaptations

3.1.4. Session 4

The exercise for session 4 was the reverse of session 3. Instead of ascending notes, a series of descending notes appeared here, which did not cause the student any problems. Minor errors appeared in the interventions - the substitution of the note a^1 for b^1 (bar 4) in intervention 1 and the substitution of the note d^1 for f^1 (bar 3) in intervention 3.

The overall improvement in notation reading was also reflected in the improvement in the mallet position. In the interventions where the mallet position was not marked, Naira started to create her own mallet position and adapted it to correctly reproduce the pitches. On the contrary, the interventions with the color marking of the mallet position did not help her in reading the notes – rather every mistake in mallet position increased her uncertainty. In intervention 5, the substitution of mallet position in bar 11 made her hesitant, causing her to slow down the tempo, which in bars 13 and 14 resulted in playing the wrong notes. See Tab. 8.

Tab. 8 Details related to session 4.

	Intervention	Size of notation	Other adaptations
4_1	4	7 mm	Colored background
4_2	5	10 mm	Colored background + colored coding of mallets
4_3	1	7 mm	No adaptations
4_4	2	10 mm	No adaptations
4_5	3	7 mm	Colored coding of mallets

3.1.5. Session 5

Exercise 5 was randomly created by arranging notes from previous exercises. It was mostly about larger interval changes, only occasionally about a second interval. In the last session, it was obvious from observation that the student was becoming more and more familiar with the string system of the cimbalom, performing more confidently and improving her mallet placement. While she played intervention 1 without error, the same error appeared in all other interventions – she confused the note a^1 with the note c^2 . See Tab. 9.

Tab. 9 Details related to session 5.

	Intervention	Size of notation	Other adaptations
5_1	5	10 mm	Colored background + colored coding of mallets
5_2	1	7 mm	No adaptations
5_3	2	10 mm	No adaptations
5_4	3	7 mm	Colored coding of mallets
5_5	4	7 mm	Colored background

3.2. Testing through the Minuet in C major

The course of the individual tests performed on Minuet in C major is shown in Tab. 10. In post-test 1, a great improvement in the accuracy of note reading was noticeable. The tempo in post-test 1 was slightly faster, the student seemed more confident. This was also reflected in the stroke and tone color, which was firmer, and more self-confident compared to pre-test 1. Only in mallet placement there was no significant difference between the two tests – in both cases the student changed mallets only from the beginning, before the technically more problematic passages came.

In post-test 2, the greatest change occurred in note reading – the melody was reproduced with only minor errors in one bar. There was a noticeable improvement in the students' confidence in the strokes, the certainty of the play was audible on the recordings. The tempo in the post-test 2 was slightly faster, and the composition was played more rhythmically accurately.

Tab. 10 Description of interventions applied.

Instruction	Pre-test	Post-test
1 (only pitch)	27 mistakes	15 mistakes
2 (pitch and rhythm)	22 mistakes	7 mistakes

3.2.1. Details of pre-tests

Pre-test 1: At the beginning of the piece, where the melody rises in the tones of C major scale (bar 1), the student did very well. She had difficulty determining larger interval changes and the note c² (bars 3-4) which caused her to slow down the tempo. In bar 5, she confused the note c² with the note e². She performed the following melody (bars 6-7) poorly, only according to the visual idea of the rising melody. She confused several notes and finished the first part (bar 8). In the second part (bars 9-16), she did better, she was able to finish the piece to the end, but she confused the second intervals with the third ones.

Pre-test 2: At the beginning of the first part (bar 1), the student managed to play the correct pitch and rhythm of the notes. In places where there was a combination of eighth notes and third intervals (e.g. bar 4), she was no longer able to reproduce it correctly. In the second part (from bar 9), quarter notes became the guiding points, the other notes were rather improvised. She could no longer read notes in combination with lengths.

3.2.2. Details on post-tests

Post-test 1: During the piece, only minor errors appeared (e.g., confusion with notes higher or lower by a second), but she quickly corrected them. It was obvious that she visually checks the musical notation and monitors the melodic structure of the piece by ear.

Post-test 2: The first part (bars 1-8) was played with the correct pitch and rhythm of the notes, except for a minor error in bar 4, which she immediately corrected. In the second part (bars 9-16), only minor errors in the pitch of the notes appeared in bar 16 (a measure with eighth notes and third intervals in the melody).

3.3. Analysis of interview

Naira chose to play the cimbalom voluntarily, based on attending a concert where her friend played the cimbalom. She had strong motivation to play the cimbalom, she enjoyed playing, but considered reading music to be her biggest problem. Naira's mother described it this way: "Naira didn't read music at all, she was always completely lost in it. When she had that small music notation, she would completely struggle and walk away from it. She would sit at the cimbalom for 5 minutes, she couldn't do it, so she threw away the sticks and gave up." Regarding SMN reading, Naira said that she had trouble navigating

the music staff, because the notes "seemed to cross each other". It was more challenging to read notes in the gaps between lines than on the lines.

As for the visual adaptations, she said that they all helped her. According to her mother, during the research study, Naira started to read music on her own. Previously, her mother had to be present during Naira's practice the whole time and help her read the music. This way, Naira learned the notation by heart. Now, her mother is only present briefly at the beginning of practicing new pieces.

The mother also sees a positive change in the length of attention span during practice. From the original approximately five minutes, the exercise was extended to 30 minutes during the research study. Naira reportedly also improved in reading and stopped going to reading intervention at school. According to the mother's experience, music can help students in various areas: "...children who have learning disabilities know this about themselves. They know that something is wrong, and it brings their self-confidence down. Especially when a teacher deliberately points it out. Even classmates see it and point it out. So, they can calm down with the music and they are often good at that music, so it can help them with their self-confidence."

4 DISCUSSION

This case study offers several key findings:

1. Naira made huge progress in reading notations during the study, but there were no essential differences related to visual adaptations. Therefore, this progress could be rather attributed to training in notation reading itself. This improvement had a huge psychological effect, positively influencing Naira's motivation, increasing her self-confidence and accelerating her progress in her studies.
2. Notwithstanding the uncertain effect of the interventions applied in this case study, Naira subjectively reported that all visual adaptations were helpful.

Although previous studies (Flach et al., 2014; Raviotta, 2017; Solis, 2010; Langendonck, 2019) reported possible benefits of UMN for students with SLD, these students could probably highly benefit also from short-term intensive training of SMN. Visual adaptations should be identified due to the previous assessment of students' deficits related to SMN reading. The visual stress that Naira described as "notes crossing" in this case study, was related to specific patterns of errors. Interestingly, Naira made more mistakes in second transpositions (confusing a note with one immediately above or below it – these mistakes are typical for non-dyslexic children) than in third transpositions that are common in dyslexia (Jaarsma et al., 1998). In test results, it was manifested in difficulties in the exchange of tones between staff lines (typically c^2 and e^2). Also, reading the ascending rows of tones was challenging.

Based on this experience, we hypothesize that the most effective visual adaptation for Naira would focus on visualization of the line dividing the tones c^2 and e^2 (e.g., by color), and on visually distinguishing the first and last tones in ascending rows of tones. However, it was not possible to identify these strategies because of the absence of a proper assessment tool that could help us to evaluate Naira's cognitive-perceptual profile related to reading SMN.

Therefore, we tried to find out if the authors of previous studies used any advanced classification of SLD challenges related to SMN reading during the initial assessment of their participants. As an example, Flach et al. (2014) divided the study cohorts into students with dyslexia, without dyslexia and students experiencing reading difficulties. For background information they explored information on the respondents' reading, music education and color-blindness. Although this study makes an important contribution to the area, detailed analysis of sight-reading specifics of children in the cohorts is not available and only the effect of UMN is described. Rogers et al. (1991) provided general information on the research sample, e.g., all the participants were beginning instrumentalists. Similarly, Solis (2010)

didn't offer many details about the participants except their diagnosis and the choice of colors for overlays. No study offers a typology of difficulties related to notation reading, most likely because no typology has yet been created. It is possible that in all previous studies, samples of students with SLD consist of participants with heterogeneous cognitive-perceptual challenges that only partially respond to the choice of the visual adaptation strategy.

Another interesting lesson we took from this case study is the inconsistency between the uncertain effects of visual adaptations found and preferences of the girl. Naira undoubtedly improved her abilities to read notation throughout the course of the study. She attributed this improvement to the application of visual adaptations although it was caused most probably by other factors. This was clear after a comparison of the findings from different tests and detailed analysis of her reading results. In the educational practice, the real causes of the improvements in notation sight-reading made by students with SLD may be very difficult to distinguish. Although the preferences of students are important for teachers to consider, more objective SMN sight-reading assessment methods should be available. Without these tests, it is challenging to design a proper teaching plan for a student with SLD.

4.1. Recommendations for practice and further research

The findings of this case study have important implications for educational practice and future research in the application of SMN for students with SLD. We suggest that visual adaptations of SMN should be indicated based on careful assessment of each student's cognitive-perceptual profile related to pitch and rhythm reading. To create such tests, a systematic typology of challenges in SMN reading should be explored and created.

Based on the findings of this case study, and our expert experience, we recommend that these tests be available in the form of a digital application with the ability to set up various parameters, e.g. the type of musical instrument (and the corresponding type of notation), tonal range, rhythm of notes, number of bars, interval spacing, types of the most common difficulties (e.g. omitting a note in a tone row or reading notes between lines), and others. The digital application could optimally set up the level of test difficulty for each respondent according to the parameters entered at the beginning of testing. Although there is scarce availability of tests used in previous studies (Flach et al., 2014) we didn't consider usage of these tests for this case study because they did not meet the specifics of cimbalom notation and the needed level of difficulty. In this digital application, it would be helpful to be able to test the effects of visual adaptations. This assessment would enable us to design an effective intervention plan for SMN reading. Also, it could be used by other professionals, e.g., by music therapists.

In the context of the Czech EAS, we suggest there is a need for closer cooperation between counselling centers and teachers from EAS for students with SEN. Deeper understanding of students' cognitive-perceptual profiles related to SMN requires expertise in psychodiagnostics, special education and related disciplines offered by counsellors. Also, the preparation of EAS teachers in interventions related to SLD could be more developed and support students with SLD from experiences of poorly informed pedagogy. In our case study, Naira repeatedly experienced reading SMN from xeroxed, poorly readable and many times reused notes with previous teachers. However, this example is not exclusive to the Czech educational system (Polínek, 2020), as studies from other countries report similar problems (Salvador, Paisali, 2017).

In addition to proper assessment and development of teachers' skills, students with SLD may benefit from intensive interventions focused on pitch/rhythm reading. These interventions must be targeted to the student's individual needs to achieve the best improvements.

4.2. Strengths and limitations of the study

The limitation of this study is its design and generalizability to populations of students with SLD. Since there are no standardized tests for measuring pitch error when playing from SMN, we created our own

tests, which, however, did not have sufficient reliability. Mainly the level of difficulty of music exercises was probably not comparable for all sessions. Interventions in which the mallet position was color-coded were more demanding, because in addition to the requirement to reproduce the correct pitch, the requirement to adhere to the prescribed order of mallets was added. However, this case study provided a valuable lesson to take with important implications for research and practice. Mainly, the creation of tests for SMN sight-reading in students with SLD may be essential to research effectiveness of visual adaptations in future studies.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/doi/s1, Appendix 1>.

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Abbreviations

The following abbreviations are used in this manuscript:

EAS	Elementary Artistic School
SEN	Special Educational Needs
SLD	Specific Learning Disability
SMN	Standardized Music Notation
UMN	Unconventional Music Notation

Appendix A*Appendix A.1***č.1****č.2****č.3****č.4**

č.5



Minuet in C Op.1 No. 10

Alexander Reinagle



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