Narrative Review

Visual Acuity Assessment in Deaf-Mute Children: Identification of Shortcomings and Search for Solutions in the Russian Federation and Some Countries Formerly Part of the Soviet Union – A Narrative Review

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ABSTRACT

The purpose of this narrative review is to study the problems in assessing visual acuity in deaf-mute children. We identified various methods of Visometry, published articles and patents for the inventions based on the assessment of visual acuity in deaf-mute children in the Russian Federation and parts of countries formerly part of the Soviet Union, in order to identify shortcomings and search for solutions. According to the total number of 126 cited scientific papers, the most common methods for assessing visual acuity in deaf–mute patients included Golovin-Sivtsev table (89.1%) and new JEI/JEI technique (8.9%). However, 2% of the doctors used tables of "illiterate" E, Teller Acuity cards with hand gestures, combining Teller Acuity cards with hand gestures to trigger reactions, Lea symbols with visual cues enabling visual cues or pointing to stimulate recognition and Graphic tables with sign language. In the presence of signs of hearing and speech disorders in patients, it is recommended to consider the use of cards duplicating optotypes to the table for assessing visual acuity

Key Words: Visual acuity, Deaf, Mute, Russia, Hearing impairment, Speech impairment.

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INTRODUCTION

Vision plays a central role in the development of newborns and young children and early visual impairments can affect development of motor skills, cognitive functions, social and communicative abilities, as well as the formation of social relationships. One of the main indicators of development of vision in children is central vision, the assessment of which presents certain difficulties when examining children. The subjective component, involving the verbal participation of children in the assessment of optotypes, complicates the assessment of visual acuity, especially in cases of any hearing and speech disorders.

Visual disturbances in deaf-mute children occur in 30-35% of cases, most commonly due to refractive errors.[1-3] According to the World Health Organization, hearing impairment affects about 650 million people, this is every ninth inhabitant of the planet and more than half of them suffer from disabling hearing loss. More than 13 million people with hearing impairments live in Russia, including more than 1 million children.[4] When examining patients with hearing impairments, visual defects were found in more than a quarter of cases and most common among them were refractive errors.[5]

Various methods of visual acuity assessment are based on the evaluation of signs (optotypes) of various sizes presented in the form of printed tables, a sign projector, a transparent (illuminating) device and on a computer monitor screen.[6,7] The existing methods of visual acuity assessment can be divided into subjective and objective. Subjective methods, in turn, are divided into indicative and tabular variants. The basis of indicative methods is the potential reaction of a child to light, an object or an object located at various distances. Indicative methods are usually used in the examination of children of the first years of life. Tabular method is based on the ability of the subject to distinguish optotypes of various sizes and configurations located at a certain distance. Objective (that is, not requiring the child's “participation”) methods for assessing visual acuity (visual evoked potentials, optokinetic nystagmus) involve the registration of functional indicators that indirectly indicate the distinction of the objects presented to the subject.

According to international recommendations, tables for examining visual acuity in young children should meet seven main criteria.[8]

1. Optotypes should be black on a white background.
2. The test must include displacement elements.
3. The optotypes used (figures and letters) should be approximately of the same legibility.
4. The horizontal distance between adjacent optotypes should not be less than one optotype.
5. The vertical distance between the optotypes should not be less than the height of the larger of the two lines of optotypes.
6. At least five optotypes must be displayed in each line.
7. The sizes of optotypes should have a geometric progression (constant ratio) of step sizes equal to 0.1 logarithmic units per line.

Of the methods used in ophthalmological pediatric practice, only the Lee, Patti and ETDRS tests meet all seven criteria.[8] Further research is needed to establish appropriate age limits for normal visual acuity for many pediatric tables currently used in clinical settings, as well as to develop thresholds for normal and abnormal results for use in the screening process. Appropriate specificity and sensitivity values are also required for each test.[9]

Reliable determination of visual acuity in preschool children using tables including optotypes of various sizes and configurations is associated with certain difficulties, primarily due to the lack of full contact, as well as difficulties in children’s perception and interpretation of the objects presented. These problems in the examination of deaf-mute children are aggravated not only by the difficulties of contact between the doctor and the patient, but also by a number of features of the development of this contingent of children. In children with hearing impairments, a normally functioning visual system is the basis for the development of effective communication and information acquisition skills.[10] It is noted that refractive errors, difficulties in maintaining visual attention and oculomotor disorders are more common in children with hearing impairments compared to children with normal auditory perception.[11,12]

In a comparative study of primary ametropia in patients with hearing impairment and normal hearing on the basis of subjective and objective tests revealed that hypermetropia, myopia and astigmatism with hearing impairment was seen in 21.9, 7.8 and 21.9% of cases, respectively. In the control group, the frequency was 17.6, 13.2 and 14.7% for hypermetropia, myopia and astigmatism respectively.[13] In another study of deaf children, half of the cases had un-noticed visual defect.[14]

The prevalence of birth defects causing hearing impairment is 0.1–0.3%, and more than 20 million people in the United States suffer from hearing impairment.[15] In people with profound hearing impairments, the detection of environmental changes and the orientation of attention primarily depend on vision, and sensory deprivation is associated with cross-modal neuroplastic changes in the brain and visual impairment.[16-19]

Based on functional magnetic resonance imaging, it was shown that people with hearing impairments have an asymmetry of perception with peripheral vision and a delayed reaction to peripheral visual targets.[20,21] A reliable assessment of visual functions and individual correction of rehabilitation strategies are of great importance for improving their quality of life and helping them to reach their full potential.[22]

As a result of an ophthalmological examination of 279 deaf-mute students of the Li De School in Guangzhou (China), 100 children (35.8% of cases) had visual impairment of one or both eyes, which, according to the authors, exceeded the frequency of eye defects in the United States. “normal population”.[23]

Children whose vision is not supported by hearing, is less active than in hearing children.[24] Practical orientation to the properties of objects develops mainly in the third year of life. Children begin to pay attention to the size, color, shape of objects and spatial relationships between them.[25-27] The later appearance of objective actions is associated with a lack of understanding of adult speech and a slower formation of the “evaluation seeker” view, which helps to draw attention to the subject.[28,29]

The results of numerous studies presented in this review indicate that improving the methods of studying visual acuity in deaf-mute patients from the point of view of simplification and accessibility remains an urgent task.

METHODS

In this study, we examined various methods of vision assessment in published articles and patents for the invention based on the assessment of visual acuity in deaf-mute children in the Russian Federation and some parts of countries formerly part of the Soviet Union, in order to identify shortcomings and find solutions. Following keywords were used; visual acuity, visometry in deaf-mute children, cards for visometry and a set of optotypes. The search included the following search engines: Cyberleninka.ru, eLibrary. Ru, PubMed, Google Scholars, Web of Science and Google Patents. Additional documents were identified by viewing lists of links to previously identified publications. Particular attention was paid to publications describing new methods and comparing different methods of vision assessment. The search was conducted from 1950 to the date of the search (August 20, 2023).

RESULTS

Bibliometric search retrieved 126 manuscripts. The most frequently used tests in the evaluation table of visual acuity of deaf–mute patients were; Golovin–Sivtsev chart (Russian: ТаблицаГоловина-Сивцева)[30]- 89.1% and Just Evident Images/ Jonnazarov Eldor Ikhtiyorovich (abbreviated JEI/JEI) for deaf-mute children (Russian patent RU 2 703 697 C1 dated September 3, 2018)[31] -8.9%. Rest of the 2% included; Tumbling E charts, Teller Acuity Cards with Hand Gestures, Lea Symbols with Visual Clues and Picture Charts with Sign Language.

DISCUSSION

Golovin–Sivtsev chart is a standardized chart with Landolt rings for checking visual acuity in deaf-mute patients, convenient for cases when a person does not speak Russian or when he does not know it well (illiterate). It was developed in 1923 by Soviet ophthalmologists Sergey Golovin and D.A. Sivtsev, which consists of two halves, one of which contains rows of lines with printed letters of the Russian alphabet, and the other with Landolt rings. Landolt rings are rings with a gap pointing up, down, left or right.

The chart consists of two parts with 12 rows each, representing visual acuity values between 0.1 and 2.0. The left part consists of series of the Cyrillic letters Ш, Б, М, Н, К, Ы, and И in a definite order, and the right part of the chart consists of a series of Landolt C symbols. The width of each character is equal to its height, and the contours have standard 1/5 gaps of the overall size. The value D, indicated to the left of each row, gives the distance in meters from which a person with a visual acuity of 1.0 can read the corresponding row. The value V, indicated to the right, gives the minimum visual acuity needed to read the row from a distance of 5 meters. The first row contains symbols 70 mm in size (V = 0.1); the second row, 35 mm; the bottom third row, 7 mm (V = 1.0); the bottom row, 3.5 mm (V = 2.0). Black and white pattern identification at 1 arc minute angle is considered to be visual acuity of 1.0, which is around 1 mm per 3.44 m distance. A character 7 mm in size has 1.4 mm pattern gaps, so over the 5 m view distance it gives an angle of around 1 arc minute (atan(0.007/5/5)≈0.963') (Figure 1).[30]

The Sivtsev Chart is a convenient way to quickly and accurately determine visual acuity. However, in some cases, the Golovin Table (Landolt rings) is used as an additional test. The individual being tested must correctly name or point to the side of the gap in the ring that the doctor indicates or use an index finger (for deaf-mute patients). Why is such additional testing necessary for patients without hearing or speech impairments? The reason is that during driver's license or military examinations, some individuals try to cheat by memorizing the arrangement of letters on the Sivtsev Chart. Consequently, they can correctly name the letters even if they cannot see them. However, memorizing the arrangement of optotypes on the Golovin Table is nearly impossible. The gap is very small, and with poor vision, it cannot be discerned. Patients may perceive it as a solid circle.

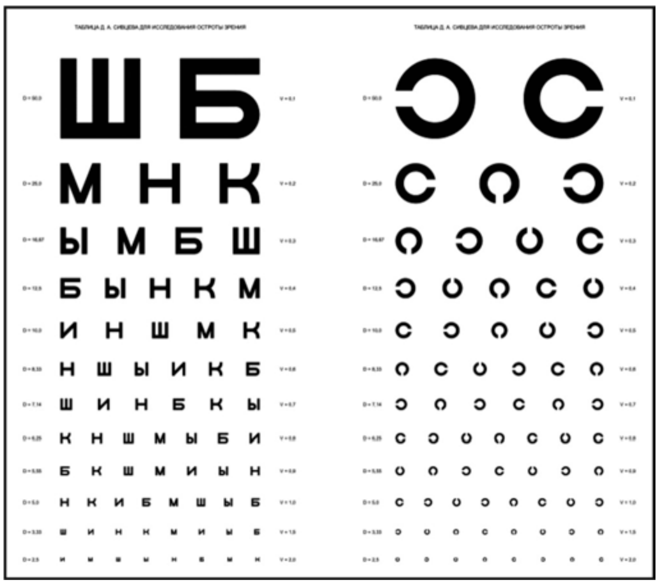

Figure 1: General view of the Golovin–Sivtsev chart (explanations in the text) - Sivtsev's chart (left) and Golovin's chart (right).

The second most commonly used method for assessing visual acuity in deaf-mute children was JEI/JEI chart. It was created in 2018 (Russian patent RU 2 703 697 C1 dated September 3, 2018).[31]Despite its relatively short history, it has become more relevant among ophthalmologists, especially when dealing with patients aged 2 – 5 years with hearing and speech impairments and presence of a language barrier due to different languages.

The set of optotypes in the JEI/JEI chart consists of 13 colored and black optotypes of different sizes, equal in width and height.[31-33] These optotypes represent well-known and easily recognizable objects for children, even at an early age. They include: “Sun,” “Flower” “Christmas Tree,” “House,” “Chick,” “Child,” “Star,” “Horse,” “Bear,” “Car,” “Kitten,” “Ball,” and “Hare.” The examination is conducted from a distance of 2.5 meters from a chart consisting of two A4-sized sheets. The chart contains 10 rows of optotypes with decreasing sizes (ranging from 35 to 3.5 mm) and corresponding visual acuity values. To facilitate a child's response, cards that duplicate the optotypes are provided with the chart.

On the first sheet of the chart, there are three rows of optotypes corresponding to visual acuity from 0.1 to 0.3 with a step of 0.1. On the second sheet, there are seven rows corresponding to visual acuity from 0.4 to 1.0 with a step of 0.1. The spacing between optotypes in each row and between rows increases from top to bottom, and in the 10th row, the number of optotypes decreases to 3 (Figure 2).[31-33]

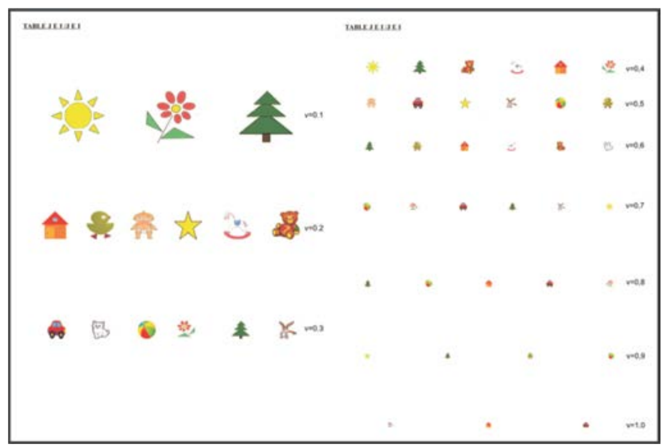

Figure 2: General view of the scaled-down JEI/JEI chart (explanations in the text).

During the examination, deaf-mute children are required to select a card depicting the sign that corresponds to the optotypes presented on the chart (Figure 3).[31-33]

For deaf-mute children, when a specific sign is displayed, the child should raise the card with the corresponding image.[31-33] The height and width of each image in the JEI/JEI chart should be equal. In the first row, the size is 35 mm, in the second row, it is 17.5mm and in the tenth row, it is 3.5 mm (see Figures 3 and 4).

The bottom edge of the JEI/JEI chart should be positioned at a distance of 35-45 cm from the floor. The chart should be placed at the child's eye level in a vertical plane so that the middle row of signs in the chart is approximately at the child's eye level. The technique for assessing vision in children may lead to earlier fatigue compared to adults, so following are the recommendations:

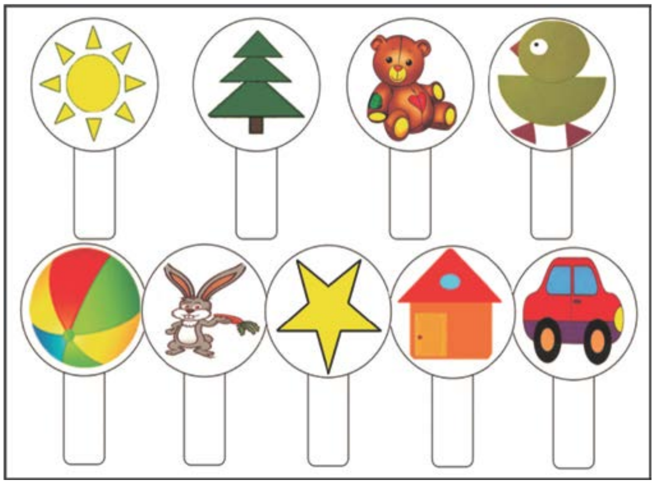

Figure 3: General view of the cards duplicating the optotypes of the JEI/JEI chart (explanations in the text).

- Begin by determining visual acuity in the better-seeing eye and then in the worse-seeing eye (if known in advance). Otherwise, start by assessing the visual acuity of the right eye and then the left eye.
- Show the child pictures one by one, starting from the top row and gradually moving downwards.
- In each row, display only one or two pictures.
- If the child incorrectly identifies a symbol in a row (raises a card with the corresponding image), give them a second attempt.
- If the child is unable to raise the card with the correct image on the second attempt, go back up one row.
- Evaluate the results based on the row where the child correctly identified all the images.
- During the test, it's important to ensure that the child does not squint or ponder their answer for more than 5-10 seconds.
- Following this, cover the second eye and repeat the same procedure.

The formula used to assess visual acuity when it is below 0.1 or above 1.0 is as follows:[31-33]

V2=(d* V1)/D

- V1 represents normal visual acuity.
- D is the distance from which a child with normal vision can see and distinguish images.
- d is the distance from which the examined child can see.
- V2 represents the visual acuity of the patient.

Use of Landolt rings is recommended as the gold standard for assessing visual acuity in deaf-mute patients. They are particularly useful in cases where a person does not speak Russian or has a limited command of the language (illiterate individuals). However, there are certain circumstances where Golovin chart (Landolt rings) give incomplete information, especially for deaf-mute children aged 2-5 years.

- Difficulties arising from the insufficient development of left-right orientation in children aged 2-5 years.
- Failure to follow the fundamental principle for charts in adults, where the relationship between the optotype detail and the optotype itself is 1:5.
- The recommended distance from the chart for assessment (5 meters) on one hand, hinders interaction with the child and on the other hand, requires a special facility, making it challenging to conduct screening examinations in preschool institutions.
- Low interest of children in the examination due to the distance from the test chart and the limited recognizability of the presented signs.
- The "dense" arrangement of optotypes and identical intervals between rows in rows 8, 9, and 10.
- Difficulties in obtaining information from deaf-mute children, leading to a significant increase in examination time.
- The inability to incorporate a playful component into the examination process.

Probability of a random correct answer using the Landolt chart with 4 orientations (up, down, left or right: 4-AFC) is 62.5%, while the probability of a correct answer with the Landolt chart version with 8 orientations (0°, 45°, 90°, 135°, 180°, 225°, 270°, 315°; 8-AFC) is 12.5%.[34] This message reinforces the idea that the use of the Golovin chart (Landolt Rings) can reduce the information.

A study compared between the Golovin chart (Landolt Rings) and the JEI/JEI chart to determine the effectiveness and accuracy of the results obtained when assessing visual acuity in deaf-mute children. It included 31 children with 62 eyes (age 2-11 years).[33] When using the original JEI/JEI chart, a significant reduction in examination time was observed compared to similar parameters using the Golovin charts. The average duration of the examination using the Golovin chart was 4.64 minutes, while using the JEI/JEI chart, it was 3.7 minutes (p=0.00003). In the follow-up examinations (OU) conducted one week later, children performed faster. The average duration of the examination using the Golovin chart was 4.58 minutes, while using the JEI/JEI chart, it was 3.45 minutes (p<0.00001).

The effectiveness of both methods was evaluated as identical using Spearman's rank correlation coefficient, indicating a moderately positive correlation.

The coefficient of test-retest reliability in the case of the JEI/JEI chart, a value close to 1 indicates a high degree of agreement between the initial and repeat measurements, signifying a high test reliability. Using the Golovin chart, in both the initial examination and the repeat examination one week later within the same group, complete consistency was observed in 28 cases (90.3%). The test-retest reliability coefficient between the initial and repeat examinations was 0.903.The repeatability of visual acuity results using the JEI/JEI chart (identical values were observed in 100% of cases for both eyes) was higher than when using the Golovin chart (90.3% for OD and 93.5% for OS, respectively).

The proposed system for assessing visual acuity in preschool-age children and deaf-mute children using the JEI/JEI chart eliminates the need for examinations at a distance of 5 meters from the chart and instead allows examinations to be conducted at a distance of 2.5 meters.[33] Furthermore, the examination process is simplified by reducing the distance between the charts and the subject to 2.5 meters and by incorporating a visual inspection, interactive games and a playful approach.[34] Thus, the reduced distance enhances the interaction between the doctor and the patient, as it introduces an element of play.

In addition to these other charts such as Lea and Orlova can also be used with modification (Figure 4 and 5).

CONCLUSION

The established principle of duplicating the presented optotypes using additional picture cards, hereinafter referred to as the “Dr. Eldor method” for visual acuity assessment in deaf-mute children aged 2-5 years, can be recommended for use in clinical practice for assessing visual acuity in deaf-mute children aged 2-5 years. This data will be valuable to clinicians, researchers, as well as test developers and manufacturers.

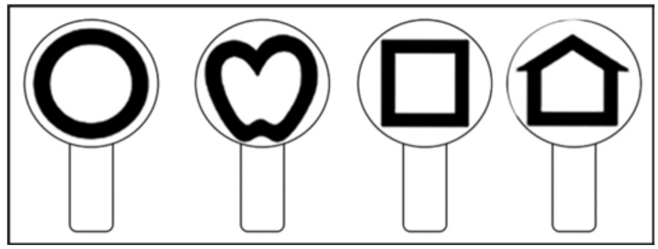

Figure 4: General view of the cards duplicating the optotypes of the Lea chart for assessing visual acuity in deaf-mute children (when showing a sign, the child raises a card with the corresponding image).

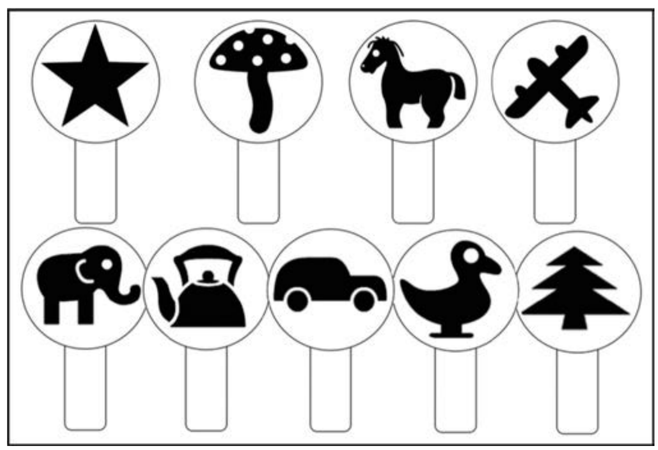

Figure 5: General view of cards duplicating the optotypes of the Orlov chart for assessing visual acuity in deaf-mute children (when showing a sign, the child raises a card with the corresponding image).

Conflict of Interest: Authors declared no conflict of interest.

Ethical Approval: The study was approved by the Institutional review board/Ethical review board **(03.22)**.

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Maria Cervatiuc; Student: *Concepts, Design, Literature Search, Data Acquisition, Data Analysis, Manuscript Preparation, Manuscript Editing, Manuscript Review.*

Pham Thai Duong; MD: *Concepts, Design, Literature Search, Data Acquisition, Data Analysis.*

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