Examination of school children's threshold exposure duration for recognition of test objects (TEDRTO) for assessment of their visual fatigue

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Background: *Due to increased visual load during schooling, it is important to use a methodology for assessment of visual fatigue in children which would be understandable to them and which would not require much time.*

Purpose: *To analyze the potential of using Threshold Exposure Duration for Recognition of Test Objects (TEDRTO) measurements for the assessment of the effect of gradual visual load on the functional status of the visual system in children of school age.*

Materials and Methods: *A special device was used to assess the effect of gradual visual load on the functional status of the visual system. The examination procedure lasted 3-4 minutes for each child. Fifty seven children (aged 13 to 17 years) with a visual acuity of 1.0, orthophoria, ophthalmoscopically normal fundi, and emmetropic refraction were examined before and after a gradual visual loading task. Their task incorporated a conventional visual load; they were to type on a computer for 30 minutes using 14-pt, Times New Roman font.*

Results: *Binocular TEDRTO values increased significantly after the visual loading task (Wilcoxon rank test; for exposures of white, red or green test object, $p = 0.000027$, $p = 0.000040$ and $p = 0.000040$, respectively).*

Conclusion: *If implemented into practice, the methodology could help to identify visual fatigue timely, and to outline fatigue prevention measures.*

Key-words:
expositional visual acuity, visual fatigue

Introduction

Ocular disease is one of the most common pediatric illnesses. Poor daily routine, imbalanced diet, hypodynamia, poor workplace design, total computerization of learning process in school and at home, and various video games are some of common causes of visual fatigue that leads to a spasm of accommodation and myopia in the child [1-4]. A substantial burden placed on the visual system usually results in visual fatigue that manifests itself as painful irritation ("burning"), reddening of the eye, frequent winking, blepharitis, etc.

Conventional eye examination techniques (visual acuity assessment, field of vision testing, etc.) do not provide an adequate characterization of the impact of visual load on the functional status of the visual system in the child. Special studies on ocular ergonomics have been introduced to determine the presence of eye fatigue. Various techniques are available for the assessment of eye fatigue (ergography, measurement of the nearest point of clear vision, accommodative convergence to accommodation ratio (AC/A), heterophonia, sequential color contrast, visual working capacity, etc.) [2, 5-12]. It should be noted, however, that some eye fatigue assessment techniques are not understandable to children, and in some instances take time. Therefore, it is important to develop a methodology for assessing the impact of visual load on the state of the child's visual system which would be very fast and understandable to children. With this in mind, we decided to use a special device for investigating the threshold exposure duration for recognition of test objects (TEDRTO). In our previous study [13] of the representative group of children (416 individuals), mean TEDRTO values in children of 5 to 6 years, 7 to 10 years, 11 to 14 years, and 15 to 16 years, have been found to be 2.2 ms ($\sigma = 1.3$), 1.4 ms ($\sigma = 0.5$), 1.1 ms ($\sigma = 0.3$), and 1.1 ms ($\sigma = 1.3$), respectively [13]. In another study [14], we have investigated biorhythms of TEDRTO in 98 ophthalmologically healthy children (aged 13 to 17 years) attending a boarding school with advanced learning of a number of subjects over a school day. These TEDRTO measurements were performed at five time points during the day (from 8 o'clock AM to 8 o'clock PM). It was demonstrated that the number of children with TEDRTO values greater than 1 ms at various times of measurement gradually increased during a school day. In addition, TEDRTO values gradually and statistically significantly increased ($\chi^2 = 52.4$; $p=0.00000$) during a school day to 2-4 ms [14].

The purpose of this study was to analyze the potential of using Threshold Exposure Duration for Recognition of Test Objects (TEDRTO) measurements for the assessment of the impact of fixed and small amounts of visual load on the state of the visual system in children of school age.

Materials and Methods

In the current study, TEDRTO measurements were performed in children attending a boarding school with advanced learning of foreign languages, at the first lesson (Computer Science) in the morning. Fifty seven children (aged 13 to 17 years) with a visual acuity of 1.0, orthophoria, ophthalmoscopically normal fundi, and emmetropic refraction were enrolled in the study. Their task incorporated a conventional visual load, they were to type on a computer for 30 minutes using 14-pt, Times New Roman font.

TEDRTO measurement methodology

Threshold Exposure Duration for Recognition of Test Objects was assessed with a special electronic apparatus. The apparatus was used to expose a test object (an illuminated Landolt's ring of white, red or green color, with a gap randomly at one of the eight positions; ring luminance, 25 candela/mm2) against a black background, with the test object presented for 1 ms to 15 ms, and 1-ms gaps between presentations. If the child failed to identify the target gap direction with the minimum exposure time, the time was increased until he could identify the direction fairly reliably, with not less than 5 correct identifications in succession. The test object had an angular size of 8 minutes of arc. Therefore, its image was projected onto the central fovea; the average angular size of the central fovea has been reported to be 1.3 degrees of arc [7]. The distance from the apparatus to the child under examination was 5 m. Both monocular and binocular investigations were performed in the morning hours, under photopic conditions. Both monocular and binocular TEDRTO measurements were performed in the morning hours, after the children performed the above visual loading task, under photopic conditions. The measurement procedure lasted 3-4 minutes in a child.

Changes in TEDRTO values after a visual loading task were analyzed using the Wilcoxon rank test and sign test. A repeated measures ANOVA was used for visualizing differences in measurement profiles. Percentages of patients with changes in TEDRTO values after a visual loading task are presented with 95% confidence intervals.

Results

Binocular TEDRTO values increased significantly after the visual loading task (Wilcoxon rank test; for exposures of white, red or green test object, $p = 0.000027$, $p = 0.000040$ and $p = 0.000040$, respectively). The use of the sign test provided additional information on the impact of visual loading on the index.

Table 1 presents the numbers and percentages of children with an increase in TEDRTO values after the visual loading task. The table shows that, with the white, red or green test object exposed against the black background, the numbers and percentages of children with an increase in TEDRTO values after the visual loading task were 23 (40.35%), 22 (38.6%), and 22 (38.6%), respectively. These changes were found to be statistically significant (for exposures of white, red or green test object, $p = 0.000004$, $p = 0.000008$ and $p = 0.000008$, respectively).

The study findings are also presented graphically (Fig. 1). With a test object of any of the three colors exposed against the black background, binocular TEDRTO values tended to be lower than monocular TEDRTO values. This agrees with a well known that binocular static visual acuity is superior to better eye monocular static visual acuity [15]. With a test object of any of the three colors exposed against the black background, TEDRTO values increased after the visual loading task. The chart demonstrates also statistically significant increases both in binocular and monocular TEDRTO between baseline and post-task values. It should be noted that the difference in binocular TEDRTO between baseline and post-task values was less significant than the difference in monocular TEDRTO. This fact also confirms the role of binocular summation in the reduction of the effect of visual load on the visual system. All children with the TEDRTO values increased after visual loading task from 1 ms to 3-4 ms complained of increased visual fatigue. These school children were advised to minimize personal exposure to excessive visual loads, maintain a balanced diet and normal daily routine, follow good practices when working at the computer, and do special eye exercises on a regular basis [1, 2, 4].

Conclusions

Examination of threshold exposure duration for recognition of test objects (TEDRTO) is a sensitive technique allowing the assessment of both the visual system influenced by visual load and the presence of visual fatigue. This examination does not require much time (the measurement procedure lasted 3-4 minutes per child) and children understand the task well. If implemented into practice, the methodology could help to identify visual fatigue timely, and to outline fatigue prevention measures.

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Table 1. Numbers and percentages of children with an increase in binocular Threshold Exposure Duration for Recognition of Test Objects (TEDRTO) index value after the visual loading task

Total number of study children	Color of the test object	Numbers of children with an increase in TEDRTO index value (n, %, 95% confidence interval)
57	White	23 (40.35; 28.6 to 53.3)
57	Red	22 (38.6; 27.1 to 51.7)
57	Green	22 (38.6; 27.1 to 51.7)

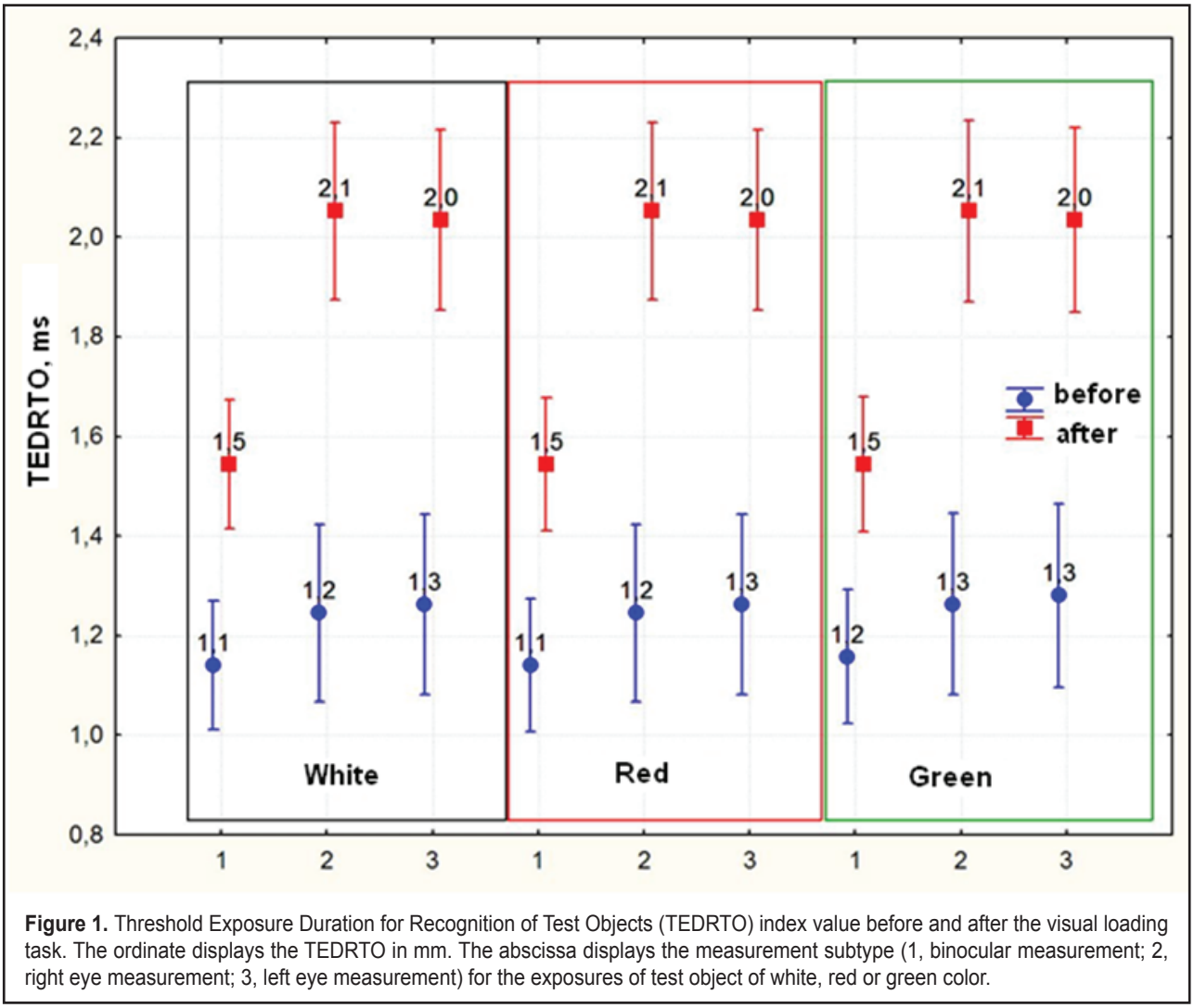

Figure 1. Threshold Exposure Duration for Recognition of Test Objects (TEDRTO) index value before and after the visual loading task. The ordinate displays the TEDRTO in mm. The abscissa displays the measurement subtype (1, binocular measurement; 2, right eye measurement; 3, left eye measurement) for the exposures of test object of white, red or green color.