Researching Students Gifted in Science Using the Method of Eye Tracking

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Abstract

Eye Tracking is a modern diagnostic method which has been recently applied in several studies. This method is based on observing human eye movement, monitoring a spot an eye is focused on, its distance, or the time duration of such focus. The course of the look, the sequence of eye fixations and movement can be widely used in cognitive sciences. This is where we class the area of pedagogical-psychological research of gifted students.

A recent pilot study of gifted students using the Eye Tracking method aimed to answer the question regarding whether it was possible to monitor the text and image processing of students gifted in science. Students participating in the study were given texts and images on a screen and asked to solve various learning tasks. Meanwhile, the processes they used to perceive the text and images were recorded. The goal of our research was to analyse the way students worked with the text, including details like whether they return to certain spots and how many times they do it within one line or one page, which words need to be focused on more than once, or how the size of their pupils changes when students think. The obtained information presents a basis for the eye movement reconstruction of individual students. Our pilot study verified that it was possible to use Eye Tracking as an experimental method even in pedagogical-psychological research of gifted students. The above mentioned also implies that there are numerous opportunities to use Eye Tracking as an experimental method in pedagogical-psychological research and that no research has so far been done on gifted students. The researchers of the Research Centre for Education of Gifted Students of the University of Ostrava have the device serving for the presented study on gifted students in science for disposition.

Keywords: Diagnostics, eye movements, Eye Tracking, students gifted in science.

Introduction

Eye Tracking (hereinafter ET) is an advanced technology method that can nowadays be applied in many kinds of research. The principle of this technology is tracking the movements of human eye, monitoring places where the eye is looking at a given moment, distance to where the eye is focusing or a period of time that an object is monitored.

During viewing an image human eye captures about 4–5 discrete perceptions per second from which the brain then composes the image. In the pilot research the author used this technology to investigate how ET can be used to monitor the work with text and picture of secondary school students gifted in science. The important thing was how students acted during the monitoring of a given text and image, which they were presented on the ET-monitor and how they were subsequently able to solve the related tasks.

Patterns of eye movements (gaze patterns) are ways in which a person progresses when reading a text. It is because we do not perceive a text or an image at once. Our brain creates them on the basis of a set of immediate and discrete sensations that arise when stopping the eye (fixation). However, during the fixation period we are able to sufficiently sharply perceive only a very limited area (e. g. when reading a text from the common distance we see with the utmost precision only about 4–5 letters. The fixations normally range from 150–600 ms according to Duchowski (2007). In average the fixation last from 250–300 ms. Fixations usually last from 100 to 500 ms (but usually about 200–250 ms) and are then followed by a series of rapid jumps to the next position of the eye fixation. These vaults, known as saccades, last about 20–40 ms and during that time the eye does not capture any information. Therefore it can be stated that the human eye captures about 4–5 discrete perceptions per second during viewing an image, from which our brain consequently puts together the final image.

The hypothesis that the place where the subject's view is aimed is also perceived by that person was outlined by Just and Carpenter (1976) thirty years ago. Currently, it is obvious that this hypothesis cannot be completely received and the focus can be directed to other areas.

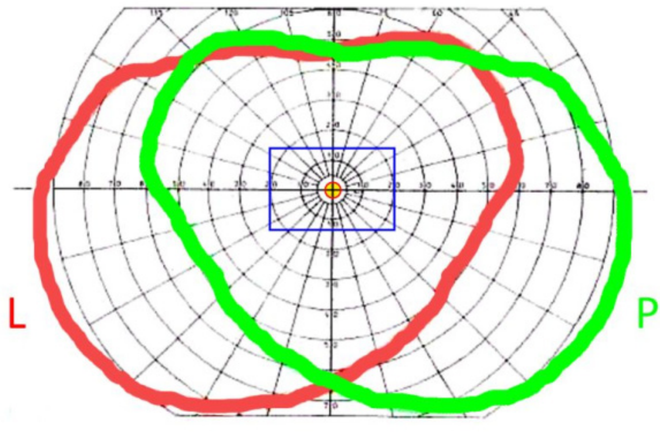
Recording and analysing the course of view, the sequence of fixation of the eye and eye movements also have extensive use in cognitive sciences. The pedagogical-psychological research of gifted students in science can also be included into this type of research.

1 Method of Eye Tracking

For assessment of the application of the ET research method in science education of gifted students it is necessary to carefully describe its essence. The ET enables tracking the movements of the human eye, then allows identifying the place where the eye is focused and other measurable quantities. We will try to describe this method in more detail.

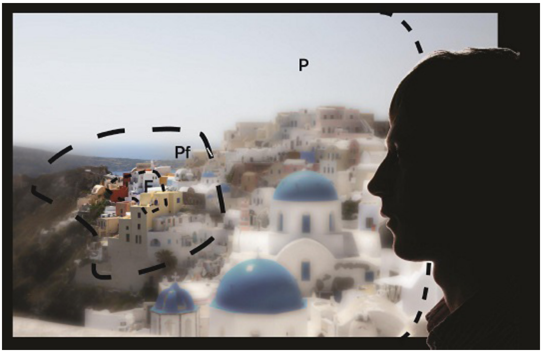
The angle of view is often determined as an angle from the axis of the rearmost effectively observed point in a given direction. However, the viewing angle also means the angle between the two extremities of the range of observation, which brings us to the concept of visual field. The field of view is the space that an eye is able to capture. In fact, we can say that the two values are equal, even though it does not seem so. The field of vision of one eye extends slightly beyond 90° off-axis of the head and in the opposite direction about 50° in the horizontal axis. Overall, one eye can see the range of over 140° of ambient image and both eyes together are able to accommodate the image at an angle of 208° in the horizontal axis. Thus we see a bit of what is behind us (see Fig. 1).

Figure 1
The range of image perception in both eyes in the horizontal axis. Available under Creative Commons licenses (author not available)



In theory, the intersection of the visual fields of both eyes is the total field of vision that we see. Everything that is out of a total field of view is referred to as peripheral vision. Practically, however, peripheral vision starts at an angle of 10° and more. Para vision se is located within the range of 2–10° while the real image as well as the viewing angle of an eye is within 2° (see Fig. 2). So the real picture looks like the picture with a black background. The residual image and its sharpness is provided by the brain. The eye, however, focuses only the point at an angle of 2° which is approximately the width of the erect thumb at arm's length (about 2.5 cm to 60 cm in length).

Figure 2
The actual image perceived by both eyes. Source Tobii.com



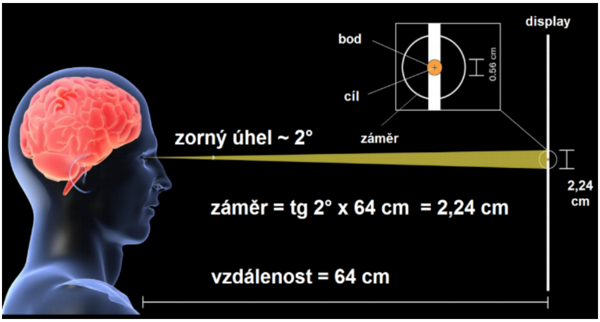
The narrow angle of vision in the macula of the retina results in the narrow angle of vision where there is the largest quantity of light-sensitive elements (rods and cones) that are able to capture the image. There are about 130 million rods that provide black and white vision and approximately 7 million cones whose function is to capture colours.

According to the previous theory it can be stated that in practice exact focus on black and white objects is better than on coloured ones. For the initial focus of the eye so-called calibration is used which is best done shortly before testing. Ideal calibration points are black and white in the largest possible quantity.

For the research presented in this paper we employed the device Eye Tracker TX 300. Its accuracy is significantly better than the accuracy of the human eye and the actual number of fixations for scanned data recording is 300 per second, which greatly exceeds the number of fixations for common scanning of the human eye in focus. The device Eye Tracker in its basic mode includes an integrated monitor which was initially used for measuring and from which was then determined and recommended viewing angle and a distance. The ideal distance from the monitor determined by the manufacturer is about 64 cm. At this distance, the human eye is able to focus on a point as large as

2.24 cm which is the size of about 2° (see Fig. 3) of the viewing angle. The device Eye Tracker is then able to target a centre point of the visual angle as large as 0.56 cm that is 0.5° at a given distance.

Figure 3
Calculation the distance of the eye from the monitor. Source Jedlicka, L. *Eye Tracker and Tobii Studio manual*

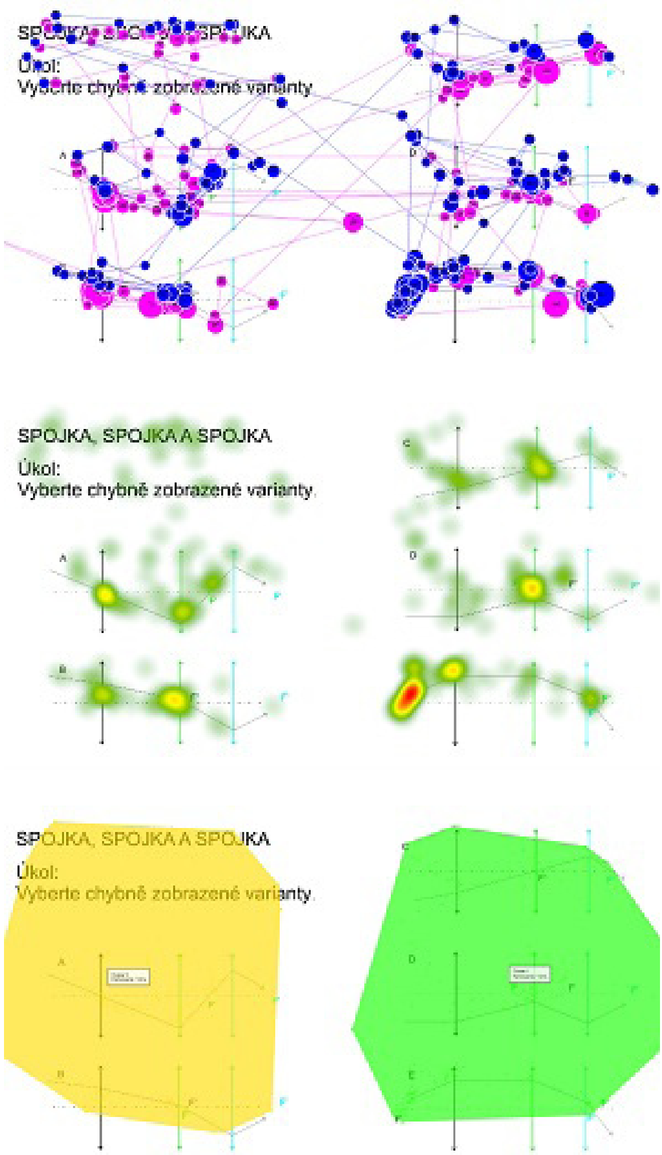


The unit records so called gaze patterns – sequential eye movements when viewing text, images, videos, etc. The movement is recorded as eye fixations (circles) and saccades (the lines between them). Taking this fact into consideration – we do not perceive the whole image, but only a part of it while the brain is calculating and making the complete picture, we can therefore say that e.g. when reading a text, we see roughly a few letters for an average of 200–250 ms and then we go on through a series of saccade lasting approximately 20–40 ms to the next fixation. During saccades the eye does not capture any information. Thanks to the fact that the device is able to record each fixation and evocate saccades among them, it subsequently displays the monitoring procedure of the scene, from which you can make additional findings (Jedlička, 2014).

The device Eye Tracker provides three basic types of view (see Fig. 4): classic view fixation/saccade, using heat maps or clusters. In this paper we used mainly fixation/saccade and heat map display.

Figure 4

Types of display of fixation clusters (gaze plots, heat maps, and clusters)



The theory used in the article has been already published (in Czech) because the text is important for understanding the research (Škrabánková, 2014).

2 Research problem and method

In our pilot study we focused on the possibility of detecting students' characteristics (variables) by the ET in solving learning tasks, assigned especially graphically. We also focused on individual differences in patterns of eye movements of different students, which can according to recent research be related to different ways of handling text and image, with problems in their understanding, etc. However it also depends on the nature of the task. Our research is primarily focused on the use of the ET for the exploration of activities of students gifted in science in text and image processing. The aim of the research was to analyse how students read given text, whether they return to certain places and how many returns within one line or page they do, which words and diagrams they stay on longer, to which words they get back to or how (at constant illumination) the size of their pupil changes when they think. This information provides the basis for the reconstruction of the eye movements of individual students and examines the possibility of using the ET as an experimental research method in educational and psychological research. The learning content which was used was the optics.

Research presented in this paper was carried out on respondents/students of upper secondary school (aged 18) which focuses on teaching mathematics and science. For our pilot study we selected a group of students gifted in science who were asked to solve a set of learning tasks. In this paper you can find as example some outcomes from one of the students gifted in science, who has been already studying the subject matter of optics. The following are not only images of fixed gaze patterns but also graphs expressing the width of the eye pupil versus time (at constant illumination). This dependence illustrates the degree of concentration of the examined student.

As the Nobel laureate in economics Daniel Kahneman (Kahneman, 2012) states in his publication entitled "Thinking – fast and slow": *"The calculation itself did not happen just as the action in your mind, the body was also engaged. Muscles were tensed, blood pressure and the heart rate increased. If someone had looked in your eye at that very moment, they would have found out that your pupils are dilated. The pupils drew back to normal size immediately after you have finished the work – whet er you found the answer, or gave up your effort."* This fact is demonstrated by our measurements as well.

As it was already mentioned above, the device Eye Tracker records the gaze patterns of the eyes (sequential eye movements) when viewing text, images, videos, etc. The movement is recorded as fixations of the eyes (circles) and saccades (lines between them).

The following are examples of outcomes of our research. There are basic texts, task assignments, observation tasks that were being solved by gifted student observations.

Learning tasks displayed on the ET monitor

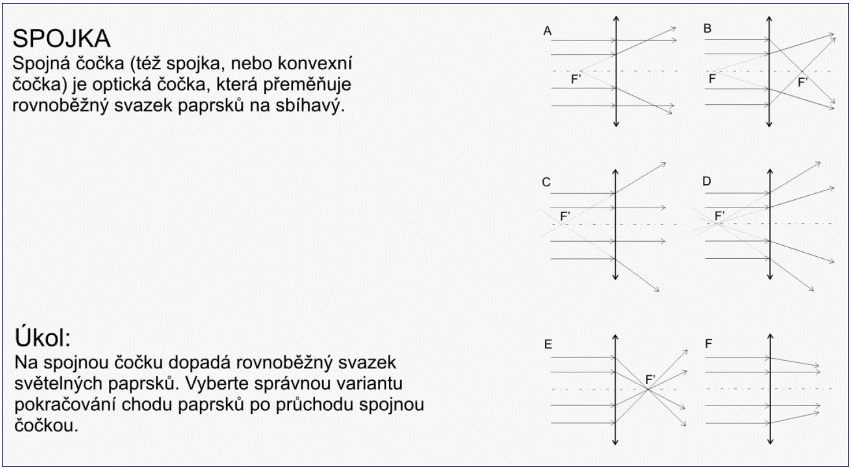
For our research we have compiled three learning tasks:

The Figure 5 presents the research form of learning task 1 on the ET monitor, which has been investigated and will be complemented by data from the ET.

Converging lens (also joint or a convex lens) is an optical lens which converts the collimated beam to converging.

Task: the converging lens is illuminated by a parallel light beam. Select the correct option of how the rays will proceed in passing through the convex lens.

Figure 5
Research form of learning task 1 on the ET monitor

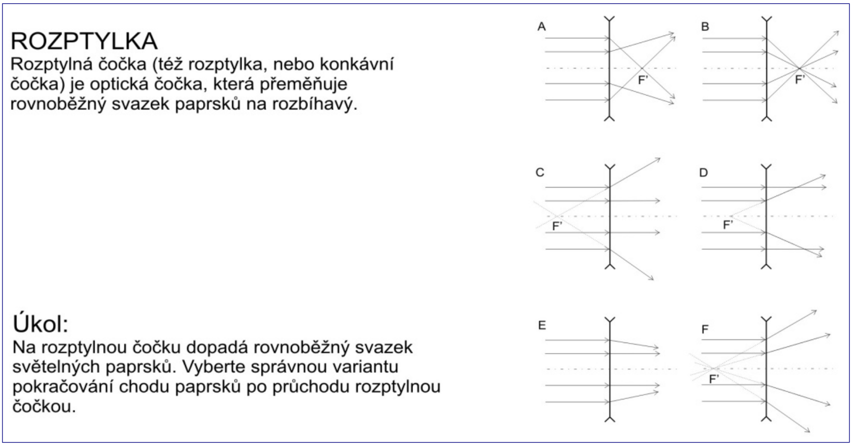


The Figure 6 presents the research form of learning task 2 on the ET monitor, which has been investigated and will be complemented by data from ET.

Diffusing lens (also diverging lens or concave lens) is an optical lens that converts the collimated beams to divergent.

Task: the diffusing lens is illuminated by a parallel light beam. Select the correct option of how the rays will proceed in passing through the lens.

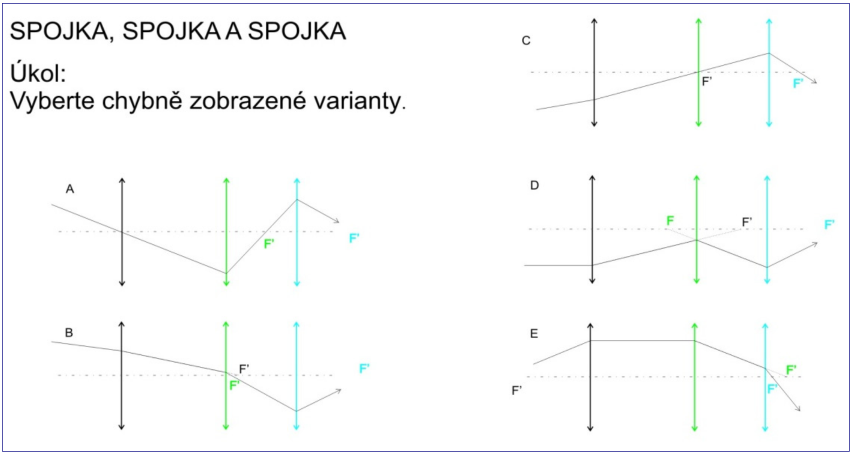
Figure 6
Research form of learning task 2 on the ET monitor



The Figure 7 presents the research form of learning task 3 on the ET monitor, which has been investigated and will be complemented by data from the ET.

Task: identify incorrect image of the rays passing through the lenses.

Figure 7
Research form of learning task 3 on the ET monitor



3 Results and discussion

Using the ET we performed monitoring of eye movements and diameters of eye pupils of the gifted student with assigned tasks and we analysed them.

LEARNING TASK 1:

Figures 8 and 9 intentionally present another possible form of how to display measurement results obtained from the gifted student. We selected only two intervals close related to the discovery of the learning task solution.

Figure 8

Sample task solutions – task 1 – interval 1

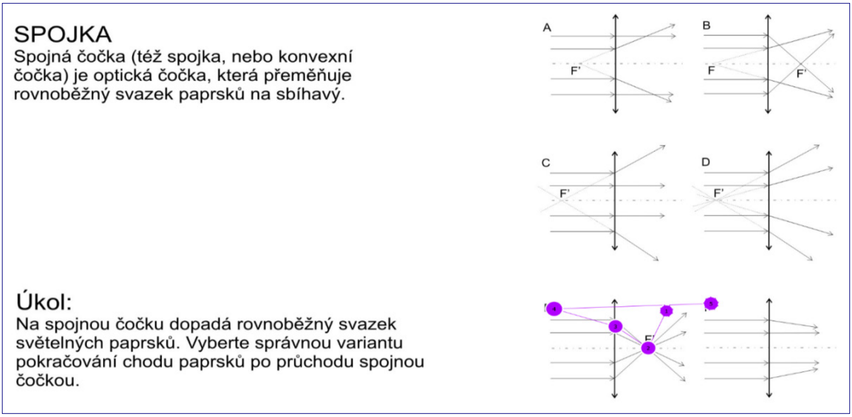
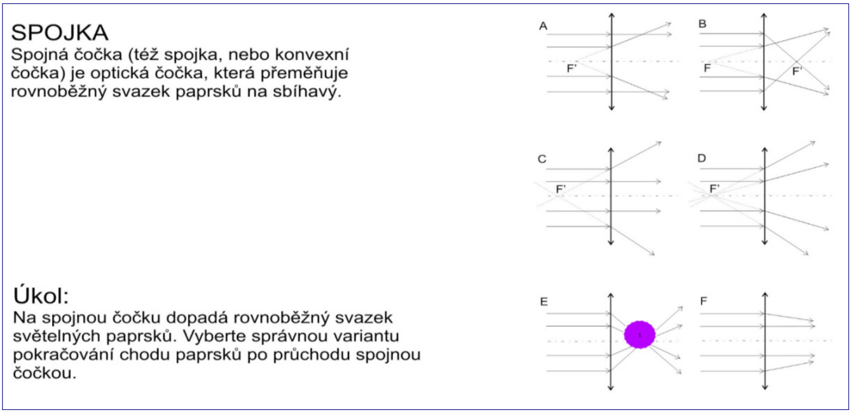
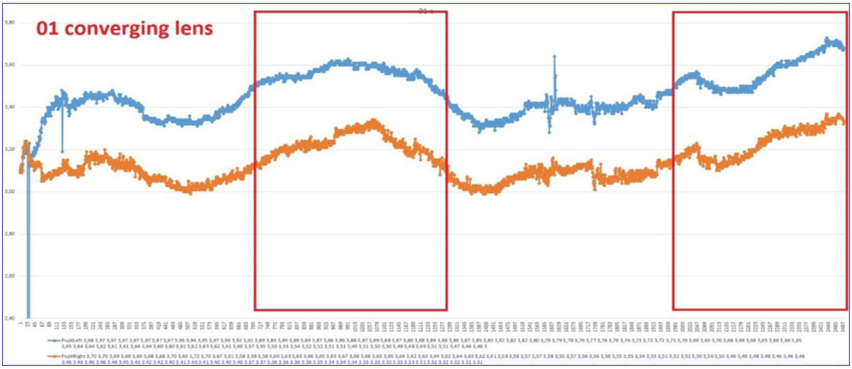


Figure 9
Sample task solutions – task 1 – interval 2



The gifted student chose the correct solution to the assigned task (option E), which has been entered in the graph in Fig. 10. When comparing the Fig. 8 and 9 with marked areas in the graph of Fig. 10 it is apparent that in given intervals the student's eyes widened. His attention and concentration increased. These relations clearly show the link between the degree of concentration of the student and the discovery of the correct solution to the task.

Figure 10
Graphical representation of changes in pupil size during the solution of task 1



The same parallel can be observed also in the results of the learning task 2 that student was dealing with (Fig. 11, 12 and 13).

LEARNING TASK 2:

Figure 11
Sample task solutions – task 2 – interval 1

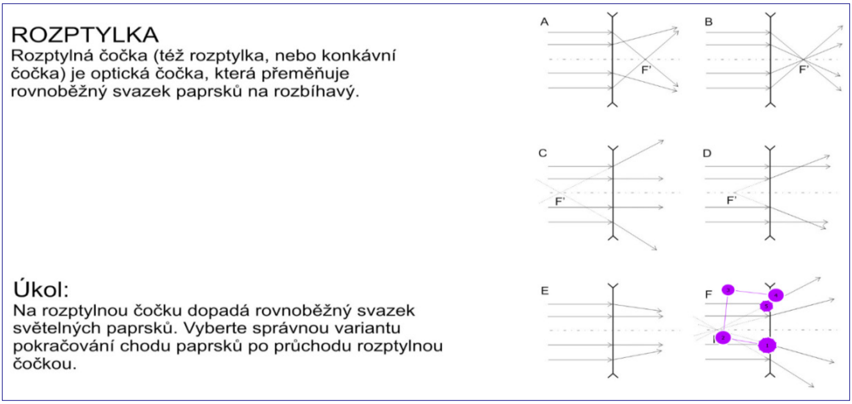
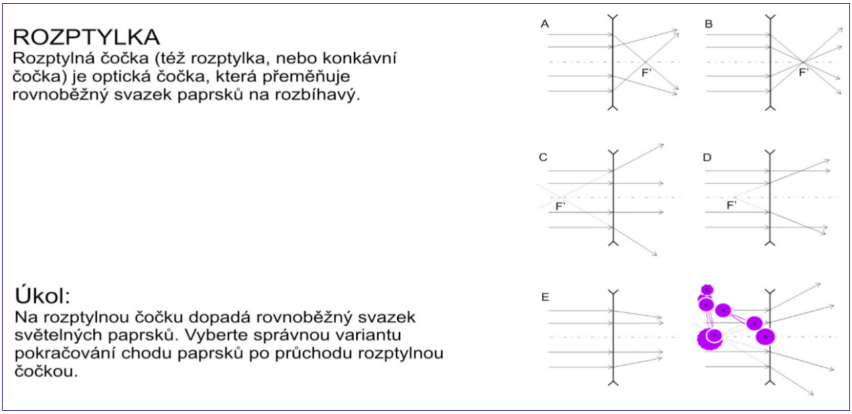


Figure 12
Sample task solutions – task 2 – interval 2



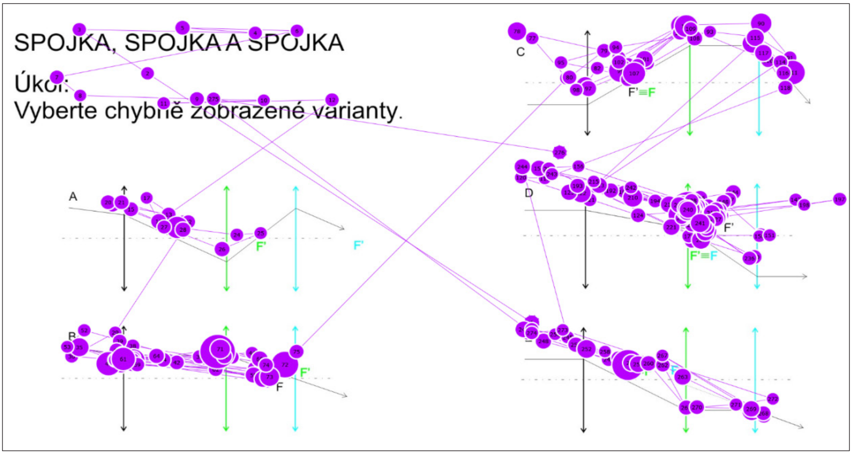
There is also (see Fig. 13) a demonstrable link between the discoveries of solutions during intervals of high concentration (the highest concentration of attention).

Figure 13
Graphical representation of changes in pupil size during the solution of task 2

The gifted student also solved more complex tasks that required their greater focus and concentration. The following Fig. 14 shows how the student proceeded in finding the right solution to the learning task 3 with three connected lenses (correct solutions are found in the options A, B and D, he erroneously omitted option C).

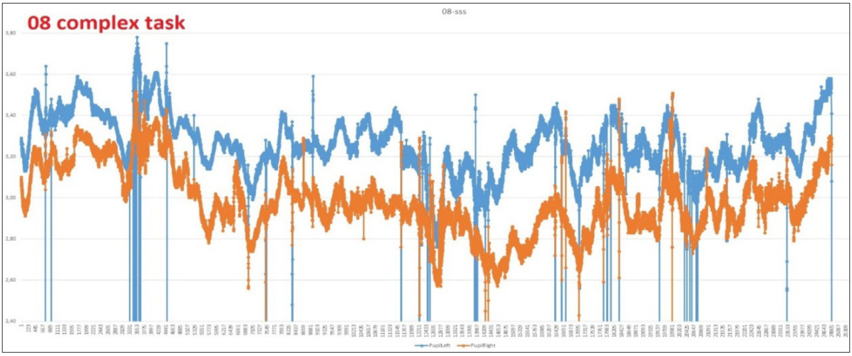
LEARNING TASK 3:

Figure 14
Sample task solutions – task 3



The procedure also corresponds with the graph in Fig. 15, where it is possible to trace the long-term concentration of the student during this task solution without significant downtime of the concentration. It is clearly visible that his attention in about halfway decreased, but in the end it increased again.

Figure 15
Graphical representation of changes in pupil size during the solution of task 3



Conclusion

Individual differences in patterns of eye movements can according to recent research be related to different ways of handling text and images with problems in their understanding, etc. However it also depends on the nature of the task. We found some interesting facts from the results we measured with gifted students, and we could read a lot of information from our findings. On the basis of fixations we measured the length of time that gifted students pay attention to solving the given task. We compared the times we measured at individual students both in relation to the way they worked with the text and the correctness of the result. We also described the process of monitoring text or image together with the subsequent solution and we have revealed the ability of our gifted respondents to concentrate on work.

There is also the possibility to estimate the extent of their concentration, which can possibly depend on the pupil diameter versus time (at constant illumination).

Thanks to our findings, it can be concluded that the ET is a suitable method for the research of gifted students. We will use it in the future to study how gifted students work with video, texts and their approach to problem solving or to be able to structure study materials for them. Our study shows that the possibility of using the ET as an experimental research method in educational and psychological research are extensive and for the gifted individuals still unexplored. The device Eye Tracker, which was used for the research of gifted students is a part of the Research Centre for educational and evaluation processes and it is an excellent research centre of the Faculty of Education, University of Ostrava.

References

Duchowski, A. (2007). *Eye Tracking Methodology. Theory and Practice*. 2nd edition. Berlin: Springer.

Jedlička, L. (20. 2 2014). *Zeptejtese.info*. Načteno z Eye Tracker a Tobii Studio manuál (ver.1. 2): http://www.zeptejterse.info/Tobii/Tobii_Studio_Manual.pdf

Just, M. A., Carpenter, P. A. (1976). Eye Fixation and Cognitive Processes. *Cognitive Psychology*, 8, 441–480.

Kahneman, D. (2012). *Myšlení – rychlé a pomalé.* Brno: Jan Melvil Publishing, s.r.o.

Škrabánková, J. (2014). Nové možnosti výzkumu nadaných studentů prostřednictvím technologie Eye Tracking (zaměřeno na přírodovědně nadané žáky). In *XXXII. mezinárodní kolokvium o řízení osvojovacího procesu: sborník abstraktů a elektronických verzí příspěvků na CD-ROM*. Brno: Univerzita obrany, s. 156–165.

Illustrations used in the study

Illustration 1. Author not available. Available under Creative Commons licenses.

Illustration 2. Reuter, P. *Tobii training Ostrava. Tobii.com* [prezentace]. [cit. 2013-07-17].

Illustration 3. Hughes, J. *Velká obrazová všeobecná encyklopedie*. [s. l] : Svojtka & Co., 1999. ISBN 80-7237-256-4. Kapitola Lidské tělo – smyslové orgány, s. 157.

Illustration 4. Jedlicka, L. *Eye Tracker a Tobii Studio manuál (ver. 1.2)*. [prezentace]. [cit. 2014-02-20].

Illustration 5. Reuter, P. *Tobii training Ostrava. Tobii.com* [prezentace]. [cit. 2013-07-17].

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