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Eye fixation and computer mouse cursor movement

The most important source of information for most people is the image in the broad sense of the word received by sight. It will be both a picture in the generally accepted sense, as well as written text. It is estimated that the eyes receive over 80% of all stimuli coming from the environment (Biecek, 2014; Zając, 2003). The percentage share of individual senses in receiving information is presented in Fig. 1. These are only approximate data because they actually depend on the characteristics of the individual.

Studies show that in the image being viewed not all elements are equally important. This also applies to written texts, including question sheets, proofreading texts and problem solving. The classic methods used so far, e.g. using the question sheet, did not show the weakest link in solving a given task, nor did they simply show that the difficulties occurring at individual stages of solving a task are different and specific for a given student. Attempts to demonstrate these difficulties required specific research and specially prepared measurement methods (Paśko, 2005).

Interest in visual attention has been noted for over a hundred years. The research was based on eye observation or introspection. To this end, a system of mirrors was used to observe while reading, magnifying glasses or even a telescope (Erdmann, Dodge, 1898; Newhall, 1928; Ogle et al., 1949). The extreme way was to

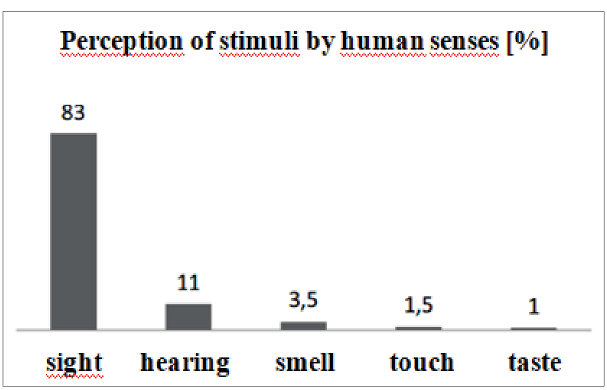

Fig. 1. Perception of the environment by individual human senses. Source: own study based on Biecek, 2014.

attach reflective elements to the eyes and record the reflection of light on the photosensitive tape (Wade, Tatler, 2005). At that time, research focused on eye movements as such, not on fixations (fixation is a relatively stable focus on the element of the image being viewed – the so-called visual scene). Measurement techniques evolved towards recording all types of eye movement. This article presents eye studies, in which modern eyetracker was used.

Until recently, eytracking was treated as a curiosity or technical novelty, today it is becoming the subject of research in many fields of science. Technical solutions becoming cheaper and, as a result, greater availability and the latest achievements in the field of eye track tracking technology, many more centers around the world are involved in eyetracking research.

Eyetracking, which is a group of research techniques, allows you to reach a wide spectrum of various aspects related to cognitive processes and human behavior. It is possible to register, measure and analyze data on the position and eye movements. Because it provides quantitative measurement data, there is no need to refer to the subjective and verbal comments of the subject, as has been the case so far. Eyetracking uses objective psychophysical and neuropsychic processes that take place during the activation, processing of visual information and during oculomotor reactions to received stimuli (Szymusiak, 2012). Therefore, eye examination is one of those techniques that has become very popular in recent years.

For eyepiece measurements, two types of eyetrackers are used: mobile (headphone, also called eyeglass) and stationary (in the form of a device integrated with a computer monitor, free-standing, whose position is manipulated by the researcher, or a system that is fully non-portable and also allows the stabilization of a person in relation to the measuring system). Mobile eyetrackers are characterized by the fact that they enable testing in the natural environment of the object, for example, in rooms with control devices (aircraft cockpit, navigation platform) or in shops, on roads, in public facilities. On the other hand, stationary eyetrackers are recommended for testing in laboratories or laboratories, when it is sufficient to register eye movements while watching materials (visual scenes) presented on a computer monitor.

Fig. 2. Pupil with light reflection on the cornea

Source: Sikora, Stolińska, 2016.

During the research procedure described in this work, a remote eyetracker was used, therefore the mechanism of his work will be briefly presented. It works without contact and allows you to study the images that are presented on the computer screen. The examined person sits in front of the computer monitor and the eyetracker camera installed, in which the infrared heater is built in. Infrared rays are reflected from the eyes of the subject, creating reflections (in physics they are called Purkinje reflections), which are reflections clearly visible in the pupils, with the help of which they can identify the spot the examined person is looking at (Schall, Bergstrom, 2014).

When eye movement is recorded by the camera, the software used in the study identifies the pupil along with the reflection of light on the cornea. This is the basis for calculating the distance vector between them and in this way you can determine the focus of sight (Poole, Ball, 2005). In order for this point to be calculated correctly, the device must be properly calibrated, which consists in displaying dots on the screen. The examined person is responsible for following these dots with their eyes, which is later analyzed in terms of the effectiveness with which the eyetracker has been calibrated. Glasses or contact lenses may cause difficulties in proper calibration because they interfere with the proper course of the infrared light beam. Therefore, it is recommended that people included in the eyetracking examination do not wear glasses and do not have eye diseases (Kaczmarek, 2012). After proper calibration, you can proceed to the appropriate tests. During the tests, the main values measured by eyetracker are saccades (saccades are abrupt changes in the position of the eyes, caused intentionally or reflexively, during which visual sensitivity decreases) and fixations, which can be presented in the form of numerical data or visualization (thanks to the processing carried out by special software). Three parameters can be used to describe fixations: time (overall or average), number and frequency. A single fixation is usually from 0.15 to 1.5 seconds (Wątróbski, Witkowska, 2015), however, it is assumed that on average three fixations take place per second, while the total fixation time is about 90% total viewing time. It is assumed that during saccade movement, visual sensitivity decreases (Bałaj, 2011). When analyzing saccadic movement, the following are taken into account: latency (time interval between stimulus presentation and initiation of the saccade in response to this stimulus, lasting about 150–300 ms in a healthy person), amplitude, duration (typically about 40 or 50 ms) and angular velocity, reaching 9,000 per second (Wójcik, 2011). Sakady are interpreted as the fastest movements our body makes and usually last no longer than 80 ms. About 10% of the total image viewing time is the total time of the Sacramento. Among the most commonly used forms of graphic presentation of data obtained by eyetracking are: eye paths, heat maps and analysis of areas of interest (Horsley, 2014).

Eye examinations are used in:

- medicine, including in the diagnosis of diseases such as Parkinson's disease or Alzheimer's disease – mainly in the early stage of disease detection (Kuec et al., 1977; Ober et al., 2009; Anderson, MacAskill, 2013),

- human-computer interaction studies (HCI – Human Computer Interaction). Eyetracking is widely used for research in the field of marketing, especially in advertising ergonomics (Poole, Ball, 2005) and website usability research;
- analysis of consumer decision-making processes (Wedel, Pieters, 2015);
- developmental psychology for the study of sensory-motor development, emotional and cognitive development of a person from infancy to old age, including research on developmental defects, including autism (Pelphrey et al., 2002);
- educational research on:
  - optimization of educational materials presented in a visual form (Nowakowska-Buryła, Joński, 2012),
  - efficiency and learning strategies based on conceptual maps, conceptual diagrams and non-linear text layouts (Amadieu et al., 2015),
  - reading process – the impact of word frequency, their difficulty, semantic meaning or the phenomenon of predicting and scanning content on the process of understanding the text (Hyönä, Lorch, 2004),
  - information processing and processes related to visual attention – how attention is directed during visual scene analysis and differences in content exploration strategies (also illustrated) between novices and experts (Stolińska et al., 2014),
  - adaptive remote education systems (dynamically adapting to users) and intelligent tutorial systems, whose task is, among others, to detect the state of involvement of learners e-learning (in particular, their curiosity and boredom), and as a consequence support for self-regulated learning processes (Jacques, 2014; Gütl, 2005),
  - various aspects of the task solving process (Błasiak et al., 2015).

Eyetracker research is very helpful in understanding perceptron and information processing processes, which is why they help collect valuable material, among others for scientific considerations. It was only thanks to this technique that some relationships were discovered that previously researchers could only hypothetically assume. Eyetrackers that follow the path of vision show what the subject is looking at and allow identifying the areas in which he focuses. Eyetracking research allows to determine the potential effectiveness of graphical teaching aids (Paśko, Stawiarska, 2017).

From the didactic point of view, eyetracking is a very important extension of research methods. It allows you to track and record methods of task analysis, charts, strategies for choosing answers during problem solving and searching for typical errors made at that time.

The increasing availability of technologically advanced devices increases interest in eyetracking methods in research, among others, in general didactics and in subject didactics. The results of previous studies indicate that eye-catching registration methods can be helpful for studying the order of mental operations performed by students while solving tasks.

Previous eyetracking research conducted in the field of didactics (broadly understood) focused around the analysis of the eye movements of potential respondents (Paśko, Rosiek, 2014; Błasiak et al., 2013; Rożek, 2014; Eitel, 2013, Ho et al., 2012; Tsai et al., 2012; Chan et al., 2009). This article presents the results of research on the relationship between eye movement when solving a problem in the field of nature and mouse movement when choosing the right solution.

The subject of the research is the path of sight and computer mouse while students solve a problem task in the area of nature.

The hypothesis is: When solving a problem task using a computer program, students first analyze parts of the task and then move the cursor with the mouse.

Variables and indicators

Independent variable:

- task placed in a computer program

Dependent variables:

- eye movement during task solving
- mouse movement while solving the task

The main indicators of a dependent variable are:

- number of fixations in AOI
- fixation time in AOI
- number of mouse cursor movements in AOI
- residence time of the mice in AOI

The research tool used in the research is eyetracker, a program that records eye and mouse movement – ogama, and a computer program with the task placed in it in nature at primary school level.

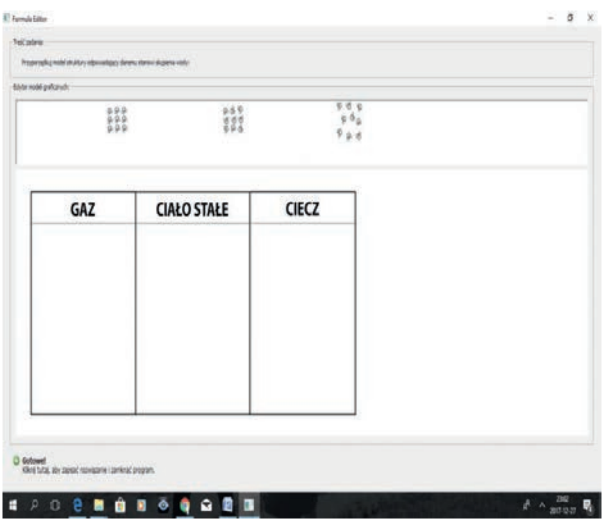

Fig. 3. Task board. Source: own study

Course of research

The students examined were at the age of 13 and attended the sixth grade of primary school in the Nowy Sącz poviat. The research was completely anonymous and participation in it was voluntary and depended mainly on parents' decisions. The principle was followed that the informed consent should be clearly documented (Czarnkowski, Różyńska, 2008), which is why parents of potential respondents expressed their written consent to participate in the study.

The tests were carried out in identical conditions for all tested people. Figure 3 presents the task board, which required the respondents to assign a water structure model to the appropriate state of its clustering:

In the task, areas of interest (AIO) were separated. Data for selected areas of interest were generated for the analysis of task solving strategies. The figure below presents the task divided into AIO areas.

In the "A" area there was the task text. Appropriate models were placed in areas "B", "C" and "D", while in areas "E", "F" and "G" there was information regarding what the model concerns. The areas "H", "I" and "J" were fields in which the mouse had to be placed by dragging the appropriate models corresponding to the descriptions placed over these areas.

Each tested student had to pass the standard "eyetracking calibration test" positively. During validation, the test subject was asked to follow the smoothly moving marker appearing at various points of the screen. Then the student went to the basic research, which was to solve his task. The answer chart was divided into three areas in which the subject was to put answers in the form of drawings from the library above the chart. Downloading this data consisted of dragging them with the mouse from the library to the marked field. The same data may have been downloaded several times.

At each stage of the study, the respondent had any amount of time to answer. The teacher was present in the examination room, but he could not answer any student questions. Dialogue during research could lead to changes in the individual's

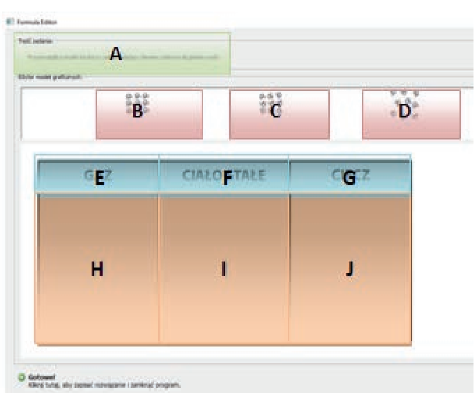

Fig. 4. Task board divided into AOI areas. Source: own study

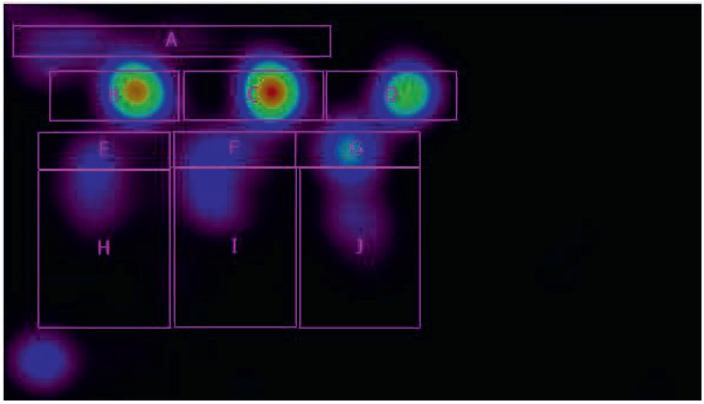

Fig. 5. Heat maps of the "sight"
Source: own study.

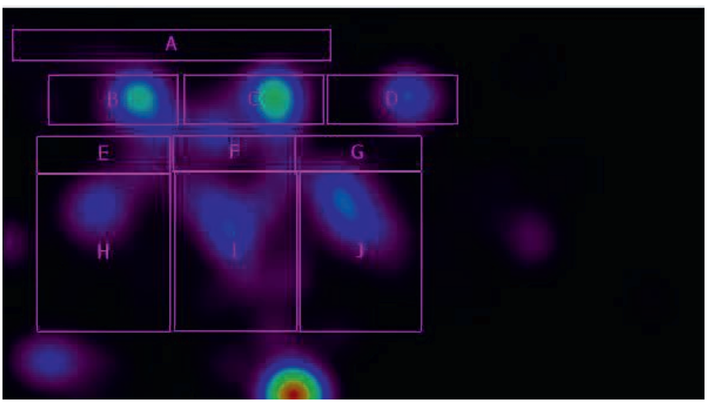

Fig. 6. Heat maps of a "computer mouse"
Source: own study.

behavior (focusing on a particular element or just the opposite – unconscious wandering around the screen while talking) (Mozol, 2011).

Findings

From the obtained data, activity maps (the so-called heat maps) of eyes (Fig. 5) and computer mouse (Fig. 6), also called heat maps, were generated. Heat maps are a graphic representation of the thermal distribution of areas that the respondent drew attention to. They simultaneously depict elements that were noticed and indirectly unnoticed by the respondent). According to the hypothesis of Just and Carpenter (1976), the location of fixations indicates the area of interest of the observer. It is assumed that the time taken by the user for visual analysis of the area of interest depends on the importance assigned to that area (Fitts et al., 1950). Red reflects the highest concentration of sight, yellow slightly smaller, and smallest blue. Black means the area omitted by the subject during analysis.

As a result of the heat map analysis (Fig. 5 and Fig. 6), it can be stated that the students analyzed the text of the task to a relatively small extent, while reading the text almost did not move the mouse cursor over it.

They showed the greatest visual activity by analyzing areas B, C and D, in which water structures were placed in various states of aggregation. Similarly, in the same areas, they showed mouse activity, but this activity was less than visual (this can be read from the colors of the heat map in this area) in areas E, F and G, in which the names of the states of water were given, little visual activity and basically no mouse activity are visible.

In contrast, in areas H, I and j, which were the fields in which the appropriate structure had to be dragged from field B or C or D, visual activity slightly less than that of the mouse was observed. This is understandable because dragging a given structure to the appropriate field was the end of the mapping.

From the research results presented above, we conclude that by moving their eyes around the board and reading the information provided to them, they basically do not mark them with the mouse cursor.

Above, the heat maps show the average results of all students. On the other hand, it is interesting to what extent the results of individual students run above this average (table 1).

Table 1. Number of fixations and mouse cursor movements during primary school students' problem solving.

Student number	Number of fixations made, sight	Number of cursor moves performed, computer mouse
1	6	26
2	37	14
3	33	7
4	94	17
5	30	13
6	16	24
7	51	24
8	28	18
9	44	12
10	16	11
11	19	15
12	24	36
13	23	10
14	53	11
15	22	14
16	12	10
17	21	12
18	34	28

Student number	Number of fixations made, sight	Number of cursor moves performed, computer mouse
19	18	5
20	18	11
21	13	11
22	13	8
23	28	9
24	16	16
25	14	5
26	31	19
27	44	34
28	69	28
29	20	12
30	48	23

Table 1 sets the number of fixations by eye with the number of mouse cursor movements.

Only in three cases, students showed greater mouse activity than their eyesight. The number of eye fixations ranged from 12 to 94. Mouse activity varied between subjects and ranged from 5 to 36 displacements.

Table 2. The number of fixations in a given AOI area by sight (W) and the number of mouse cursor displacements (M) when solving the task.

Student number	Number of fixations in AOI																			
	A		B		C		D		E		F		G		H		I		J	
	W	M	W	M	W	M	W	M	W	M	W	M	W	M	W	M	W	M	W	M
1	0	0	1	2	1	3	1	3	1	0	0	0	0	0	1	1	0	2	0	1
2	0	0	3	1	10	2	5	1	5	0	2	0	5	0	2	1	2	4	4	2
3	0	0	4	1	4	1	4	0	4	0	2	1	6	0	6	1	0	1	2	1
4	14	0	11	1	13	3	15	2	15	1	9	0	13	0	6	3	4	1	1	2
5	6	0	4	1	2	1	3	0	3	0	4	2	3	0	3	1	1	4	1	1
6	5	4	3	3	4	1	0	2	0	1	1	0	0	1	1	2	0	4	0	1
7	11	0	9	7	5	2	3	1	3	1	0	0	0	0	1	2	1	3	3	1
8	0	0	3	2	3	3	5	2	5	0	0	0	2	0	1	4	8	1	2	1
9	0	0	3	1	4	1	3	1	3	1	5	2	8	0	5	1	2	0	2	0
10	0	0	1	1	2	1	1	1	1	0	1	0	3	0	4	1	1	1	1	1
11	0	0	3	1	4	1	3	1	3	0	1	0	1	0	0	2	1	1	1	1
12	0	0	3	2	3	4	6	4	6	0	2	1	1	0	1	9	3	12	3	2
13	1	0	5	2	1	1	2	1	2	0	0	0	0	0	0	1	3	1	6	1
14	10	0	5	2	6	1	7	1	7	0	3	0	7	0	2	0	2	1	5	1
15	5	0	2	1	4	2	3	1	3	0	2	0	0	1	0	2	0	2	5	3
16	0	0	1	1	3	1	1	1	1	0	2	0	1	0	1	1	0	3	0	0
17	0	0	6	2	2	1	2	2	2	1	3	0	2	0	1	2	3	1	1	0
18	3	0	2	1	4	5	7	7	7	0	1	1	1	0	4	6	6	2	2	2

Student number	Number of fixations in AOI																			
	A		B		C		D		E		F		G		H		I		J	
	W	M	W	M	W	M	W	M	W	M	W	M	W	M	W	M	W	M	W	M
19	0	0	4	0	3	0	2	2	2	0	1	0	2	0	2	0	0	0	1	1
20	0	0	4	1	3	1	5	1	5	0	1	0	0	0	1	0	0	0	1	3
21	0	0	3	3	3	1	0	0	0	0	0	1	0	0	0	1	2	1	1	1
22	0	0	1	1	1	1	0	1	0	0	2	0	4	0	1	1	0	2	1	0
23	0	0	7	0	3	1	4	1	4	0	1	0	2	0	3	1	0	0	2	2
24	0	0	3	2	3	4	0	1	0	0	0	0	1	0	2	1	1	2	4	3
25	0	0	3	0	4	0	2	1	2	0	0	0	1	1	2	0	0	2	1	0
26	5	0	1	1	4	5	2	1	2	0	0	0	1	0	1	1	1	2	3	5
27	6	6	4	2	10	5	6	2	6	0	0	1	5	1	1	1	1	3	0	11
28	2	0	4	3	1	2	1	2	1	0	6	0	8	1	4	3	10	8	5	4
29	0	0	2	3	5	2	2	1	2	0	0	0	2	0	3	1	0	1	0	1
30	0	0	8	2	12	4	8	4	8	0	1	0	6	0	5	2	1	1	0	1
TOTAL	68	10	113	50	127	60	103	48	103	5	50	9	85	5	64	52	53	66	58	53

Table 2 lists the numbers of eye fixations and the number of mouse cursor movements in the marked AOI areas. The analysis of the obtained data shows that, in principle, students (except one) reading the text of the assignment did not follow it while marking it with the mouse cursor. However, many students did not read the assignment text. Most of the respondents did not introduce the mouse cursor to areas E, F and G, in which information about the state of water was placed, which model should be placed in fields H, I and J.

Based on Chart 1, it can be seen that the number of eye fixations in individual AOI areas was always higher (in some cases even several times) than the number of mouse cursor displacements "Only in areas H, I and J these values are similar. Areas H, I , J are large fields in which the appropriate models are inserted (dragged), so in these areas students probably repeatedly moved the entered model.

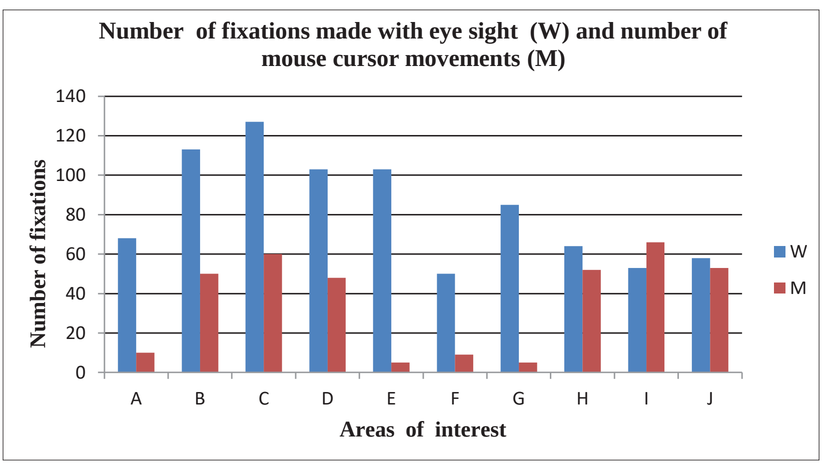

Chart 1. Number of fixations (W) and number of mouse cursor movements (M) of designated AOI areas during problem solving.

Based on the results of the study summarized in Table 3, it can be concluded that fixation times in a given AOI area are not proportional to the time the mouse cursor stays in that area. In some cases, the area was focused longer than the mouse cursor was. However, in some cases it was the opposite.

Table 3. Time of fixations [ms] taken by sight in a given AOI area during problem solving and time spent by the mouse cursor in a given AOI area by primary school students.

Student number A		**Fixation time [ms] in AOI made by sight and computer mouse cursor**									
		B	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	
1	eyesi-ght	0	6681	241	0	0	1159	0	0	234	0
	mouse	0	1655	1513	1228	0	0	0	866	974	904
2	eyesi-ght	0	2349	1687	319	1078	527	631	1138	1886	0
	mouse	0	571	4156	1298	0	0	0	702	9845	8412
3	eyesi-ght	0	1438	1683	521	1521	1661	0	662	1029	0
	mouse	0	726	3031	0	0	9219	0	486	1834	1600
4	eyesi-ght	4738	3789	4609	2460	5180	1959	1534	1296	412	4738
	mouse	0	1923	15240	1620	6189	0	0	2487	1568	1237
5	eyesi-ght	1849	1892	912	879	672	5327	304	1359	0	1849
	mouse	0	2298	1033	0	0	3976	0	706	6816	1624
6	eyesi-ght	2806	6881	0	195	0	329	0	0	0	2806
	mouse	5312	9159	395	1327	2054	0	762	1557	3674	442
7	eyesi-ght	3060	4443	1495	0	0	2537	228	549	203	3060
	mouse	0	6039	990	603	1020	0	0	1601	16492	453
8	eyesi-ght	0	2248	2170	0	405	409	2666	848	167	0
	mouse	0	1730	5473	731	0	0	0	3651	722	346
9	eyesi-ght	0	2612	1491	1348	2135	1383	502	1269	149	0
	mouse	0	3638	1127	1394	331	1933	0	415	0	0
10	eyesi-ght	0	667	146	121	612	856	163	1096	358	0
	mouse	0	400	752	293	0	0	0	1129	603	724
11	eyesi-ght	0	1961	2092	157	216	0	1216	300	1422	0
	mouse	0	406	362	832	0	0	0	878	439	1500
12	eyesi-ght	0	637	4260	428	167	305	1686	1458	0	0
	mouse	0	1298	2392	4072	0	521	0	4751	11118	1013

Student number A		Fixation time [ms] in AOI made by sight and computer mouse cursor									
		B	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	
13	eyesi-ght	168	1918	1207	0	0	0	568	1283	683	168
	mouse	0	1234	600	1493	0	0	0	509	938	612
14	eyesi-ght	4570	2768	2810	814	1212	539	435	1902	302	4570
	mouse	0	4390	3503	758	0	0	0	0	1497	531
15	eyesi-ght	1608	703	1356	615	0	0	0	1420	315	1608
	mouse	0	502	3336	635	0	0	1283	3147	1563	6211
16	eyesi-ght	0	428	131	296	136	207	0	0	677	0
	mouse	0	1064	805	735	0	0	0	848	2051	0
17	eyesi-ght	0	1772	1560	1425	382	284	1102	605	0	0
	mouse	0	977	499	848	864	0	0	1505	734	0
18	eyesi-ght	1390	819	3179	206	142	592	2478	780	407	1390
	mouse	0	728	3472	4945	0	592	0	7735	963	13160
19	eyesi-ght	0	968	773	234	266	309	0	331	489	0
	mouse	0	0	0	3461	0	0	0	0	0	1661
20	eyesi-ght	0	1236	2415	235	0	748	0	265	298	0
	mouse	0	736	501	469	0	0	0	0	0	9464
21	eyesi-ght	0	788	0	0	0	0	512	135	145	0
	mouse	0	3538	397	0	0	771	0	840	288	1081
22	eyesi-ght	0	630	0	486	1831	158	0	518	293	0
	mouse	0	688	1495	624	0	0	0	1538	1780	0
23	eyesi-ght	0	2463	1148	189	502	862	0	332	397	0
	mouse	0	0	476	466	0	0	0	1513	0	1428
24	eyesi-ght	0	1306	0	0	428	2841	261	1506	1091	0
	mouse	0	1523	8874	335	0	0	0	1255	2208	1744
25	eyesi-ght	0	1232	1329	0	121	331	0	134	0	0
	mouse	0	0	0	396	0	0	306	0	4779	0
26	eyesi-ght	1587	266	472	0	133	238	338	1179	848	1587
	mouse	0	736	5560	366	0	0	0	720	805	3506

Student number A		Fixation time [ms] in AOI made by sight and computer mouse cursor									
		B	C	D	E	F	G	H	I	J	
27	eyesi-ght	2702	2513	2279	0	894	572	540	0	5193	2702
	mouse	3256	1377	5322	3002	0	498	770	352	6822	7526
28	eyesi-ght	381	1635	237	1334	2293	2305	3082	2491	1403	381
	mouse	0	3474	1899	792	0	0	1926	3296	9193	5291
29	eyesi-ght	0	1105	545	0	947	674	0	0	743	0
	mouse	0	2311	1064	637	0	0	0	1067	6735	1729
30	eyesi-ght	0	3478	3859	262	1101	994	302	0	553	0
	mouse	0	668	2197	3107	0	0	0	869	424	1735

Conclusions

When you solve a task that uses the mouse cursor to move items from one field to another, it plays two roles. One of them is selecting the elements of the task, while the other is the shift. The use of the cursor depends on the subject. Some move it along with directing their eyes on the element. On the other hand, others use it to select certain elements and in the final stage of solving the task, when it is necessary to move the element.

Hypothesis put forward: "During problem solving with the use of a computer program, students first analyze parts of the task, then move the cursor with the mouse". It has not been fully verified. Moving the mouse cursor depends on the subject. Some use it to track the text and data of the task and others only in some cases.

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Eye fixation and computer mouse cursor movement

Abstract

The most important source of information for most people is the image in the broad sense of the word received by sight. The subject of the research is the path of sight and computer mouse while students solve a problem task in the area of nature. The research tool used in the research is eyetracker, a program that records eye and mouse movement – ogama, and a computer program with the task placed in it in nature at primary school level. When you solve a task that uses the mouse cursor to move items from one field to another, it plays two roles. One of them is selecting the elements of the task, while the other is the shift. The use of the cursor depends on the subject. Some move it along with directing their eyes on the element. On the other hand, others use it to select certain elements and in the final stage of solving the task, when it is necessary to move the element.

Keywords: education, eyetracking, fixation, computer mouse cursor movement

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