Anna Stolińska[1], Mariusz Noga[2]

Usability and performance of selected configurations of eye tracking sets in augmentative and alternative communication – case study

Użyteczność i wydajność wybranych konfiguracji zestawów eyetrackingowych w AAC – studium przypadku

Summary: The development of new technologies has contributed to the creation of new tools which enable disabled persons to communicate with their surroundings, including use of internet network resources and education. Nowadays, when so many people have moved their activity, including their professional activity, into the network environment, even people with limited mobility and speech can function actively in society. Applications, which coupled with equipment recording eye movement may provide an aid to improving computer skills, are presented and compared in the paper. Solutions that do not require large financial resources are presented. These are shown to be very valuable, and this has been demonstrated by performance tests and a usability assessment of particular configurations formulated by a user unable to speak and diagnosed with quadriplegic cerebral palsy since the birth. The information provided in the article can be used by persons who want to enable their charges to communicate independently with a small financial outlay.

Abstrakt: Rozwój nowych technologii przyczynił się do powstania nowych narzędzi, które umożliwiają osobom niepełnosprawnym komunikację z otoczeniem, w tym korzystanie z zasobów sieci internetowej oraz edukację. W dzisiejszych czasach, kiedy tak wiele osób przeniosło swoją aktywność, w tym zawodową, do

[1] Dr Anna Stolińska, prof. WSEI, Department of Computer Science, College of Economics and Computer Science of Krakow.
[2] Mgr Mariusz Noga, Department of Computer Science, College of Economics and Computer Science of Krakow.

środowiska sieciowego, nawet osoby z ograniczoną sprawnością ruchową i mową mogą aktywnie funkcjonować w społeczeństwie. W artykule przedstawiono i porównano aplikacje, które w połączeniu z urządzeniami rejestrującymi ruch gałek ocznych mogą stanowić pomoc w doskonaleniu umiejętności obsługi komputera. Przedstawiono rozwiązania, które nie wymagają dużych nakładów finansowych. Wykazano, że są one bardzo wartościowe, a świadczą o tym testy wydajnościowe oraz ocena użyteczności poszczególnych konfiguracji sformułowanych przez użytkownika niemogącego mówić i zdiagnozowanego od urodzenia z czterokończynowym porażeniem mózgowym. Informacje zawarte w artykule mogą być wykorzystane przez osoby, które chcą umożliwić swoim podopiecznym samodzielną komunikację przy niewielkich nakładach finansowych.

Keywords: human-computer interaction, eye tracking, alternative communication, electronic aids, performance tests

Słowa kluczowe: interakcja człowiek-komputer, eye tracking, komunikacja alternatywna, pomoce elektroniczne, testy wydajnościowe.

.

JEL Classification: I1
ASJC: 1706

Introduction

Augmentative and Alternative Communication (AAC) consists of all efforts which are undertaken by therapists, parents, and other persons to facilitate communication by persons with disabilities who cannot communicate by the use of speech (Holmqvist et al., 2017). In order to communicate these persons can use other methods in the place of words, such as e.g. pictograms, gestures and by their use whole sentences can be constructed and emotions can be expressed. In this case, tools commonly termed as communication aids are useful. They have been used for a long time and they include boards, devices using uncomplicated technology with the use of light and moving pointers or equipment using advanced computer technology (McNaughton and Bryen, 2007).

What method of communication can be used by a person unable to speak depends on many factors, such as the cognitive functions of a person with a disability or the ability to see or hear. It is also important if a person who is not fully capable can use his/her hands. All communication aids are used as tools to indicate. This often takes place by touch, pressing buttons or keys on the keyboard. However, indicating does not have to be achieved using a hand or a leg. Many people with movement disorders are not able to use their fingers, or to point to a specific object with them in any other way. In such situations another method of selecting elements from a set, e.g. pictograms which illustrate words, needs to be found and then modern communication aids must be used (Clarke and Price, 2012; von Tetzchner and Martinsen, 2006). In such cases devices using advanced computer technology prove most useful as they enable persons with very complex dysfunctions to communicate (Light et al., 2019; Arias et al., 2016). People using graphic signs usually use a computer program with an appropriate sign system. One such program is Boardmaker and Speaking Dynamically Pro, which is a speaking text editor that has embedded signs, scanning methods and other important options, such as, for example, program handling through buttons. In addition, computers can be used as control devices e.g. for opening doors, turning on a radio, TV set or light etc. Another way of using a computer is for education and play (Lancioni et al., 2016). When using a tablet and buttons, the disabled person can expand a mode of communication necessary for expressing their needs, and also for providing leisure (Ibrahim et al., 2018). A particular application of these tools is their use by persons with limited mobility. One of the main factors assessed while selecting a communication aid is the mobility of the user. The prime goal is that an operator should be provided with access to the possibility of communicating at all times, that is why people on a wheelchair may use relatively large and heavy aids, whereas people who can move freely should use light aids. The speed of a specific means of communication or tool is another factor which should be taken into consideration when choosing a communication aid, as alternative communication requires much more time than normal communication (Myrden et al., 2014). Nowadays it is aimed at communicating as quickly as possible. The price of the AAC devices is also of a great importance. The majority of modern electronic aids are expensive and they do not always guarantee success in communication (McBride, 2011). The ability of a person to communicate by a traditional board does not have to be improved when a modern pointing aid is used.

A communication aid using modern computer technology based on pointing may include eye tracking, that is tracking eye movements with a device using a special camera and (for instance) a laptop to see where a user focuses his/her eyes (Wilkinson and Mitchell, 2014).

Research has shown that persons with significant disabilities, including multiple disabilities, have the highest cost of living (Mitra et al., 2017). In this case it is necessary to spend additional funds not only on health services, medicine, help in daily activities, but also on the communication aids themselves. Eye-tracking sets which differ significantly in price are compared in terms of their functionality, performance and usability.

Computer technology using eye tracking

Eye tracking is a process used to determine the point on which the eyes are focused by following eye movement. Devices called eye trackers are used for measuring the position of the eye (Stolińska and Andrzejewska, 2017). These devices are used in the visual system, in psychology, psycholinguistics, marketing, as input devices in human-computer interactions. They are also more and more frequently used for communication with persons with autism (Gillespie-Smith and Fletcher-Watson, 2014) or motor dysfunctions with a speech disorder (Chen and O'Leary, 2018).

In order for an eye movement recording device to fulfil its task, it should provide a computer with information on the specific location of the visual focus of a user. Therefore, the most desirable type of input data for an analysis of eye tracking to estimate the estimated Point of Regard is that indicating the coordinates (x, y) of the point at which a user is staring (Santella and DeCarlo, 2004). Eye tracking devices perform a tremendous quantity of computing work and without integrated processors take up much of the computer memory to which they are connected. If an eye tracker is to serve as an aid to alternative communication, it may be considered worthwhile to have an eye tracking device which does not need the high computing power of a computer, as the devices which are most frequently used are small tablets or notebooks.

Programs using an eye tracker for operating a computer

There are many applications for eye tracking which can be classified into two categories: diagnostic and interactive applications. Where the diagnostic role is involved, an eye tracker only provides data concerning eye movement. As an interface module, the eye tracker serves as an input device which can be used by many applications for diagnostics (Al-Rahayfeh and Faezipour, 2013). These applications are characterised by discreet use of an eye-tracking device (a camera). In some cases the applications deliberately hide eye-tracking information so that potential patients are not aware of this function. Typical statistical measurements can include a number of fixations on the specific area (Area of Interest, AOI) during a few-minutes long session of viewing an image displayed on a screen. The diagnostic techniques of eye tracking are used e.g. in the fields of psychology, psycholinguistics or marketing (Duchowski, 2017).

A computer equipped with an eye tracker as the input device and with appropriate software can provide an interaction with an operating system (Vazquez-Li etal., 2016). Interactive systems can be classified into two subtypes of application: selective and visually conditioned. Selective systems can be compared to pointing devices such as a mouse or a keyboard, as they use data on eye position to select or point. Visually conditioned systems use data on eye position to operate complicated displays. The basic application for interactive eye tracking is one in which a user's gaze serves as a pointing tool. This mechanism can be used to facilitate communication, and even to control a computer without using a mouse or a keyboard. (Duchowski, 2017, p. 247).

Interactive applications in which user's eyesight forms the input data include, among others, Optikey, Windows Control and an eyesight control option available in the Windows system, which is currently in the beta system, but just like other applications, provides a complete interaction with the system using the eye tracking technique for this purpose.

As you can read on the Optikey manufacturer's website, they offer a free package of applications operating in the Windows system. This package allows communication with and use of a computer using one's eyes alone. Optikey was written to challenge very expensive, unreliable and difficult to use AAC products. It is, therefore, fully open source and free of charge. A version of Optikey Pro provides full control over the computer, mouse control, writing, speaking and much more. When writing, the program provides the function of predictive text and it services a few languages. Optikey Pro can be used as an alternative to a physical keyboard, facilitating writing in any application and automatically inserting spaces between the words and upper case letters to increase speed of writing (Kelway, 2018). It also permits the addition of whole words and phrases to memory. Optikey Pro can replace a mouse, allowing precise clicking, scrolling and dragging the mouse cursor anywhere on the screen. Considering that Optikey is an open source application, it can be freely extended by other programmers. You can find information on how to support the development of the application on the manufacturer's website (OptiKey, 2020).

Another application from the interactive group is Windows Control, which is produced by the Tobii Dynavox company. It costs about 650 Euro. On the website the manufacturer informs us that the application, together with the eye tracking device, offers full access-by-looking to a computer with the Windows system, thus replacing a mouse and keyboard. This application allows one to hit a smaller target using the unique zoom function, which provides control over where a user points, clicks or drags. The application also offers efficient high speed access to all computer functions, with a small number of errors and clicks. Shortcuts in the Windows system control increase even further the speed and comfort of computer use owing to direct access to the desktop, windows, volume adjustment, cut/copy and paste options and many other features. Built-in keyboards contain the SwiftKey word prediction function which learns writing style and words and phrases that are important to a user, constantly adjusting to his/her writing style. Owing to this knowledge, the keyboard suggests proactively what a user will want to write next. Currently, word prediction is available in 30 languages (Tobii Dynavox, 2020).

Eyesight control in the Windows 10 system is available from version 1709. This option is still available in a test version, but nevertheless provides simple and full access to operating the Windows system using one's eyesight. The eyesight control is available in all regions, however the keyboard controlled by eyesight only services the EN-US keyboard layout, and some settings of the eyesight control are available only in the English language. In order to activate the program it is enough to connect one of the eye trackers, for example: EyeTech TM5 Mini, Tobii EyeTracker 4C, Tobii EyeX, Tobii Dynavox PCEye Plus, Tobii Dynavox EyeMobile Mini or Tobii Dynavox (Get started..., 2020).

It is worth mentioning that other application projects supporting communication using eye tracking of the EyeGem, Soma Eye Tracking or PyGaze type, have been developed for a number of years now (Dalmaijer et. al., 2014).

Eye tracking devices used during testing

A comparison of the devices used during testing is presented in Table 1. The main difference between them is their use. The Tobii EyeTracker 4C camera is a dedicated device for gamers and its price is relatively low, whereas the EyeMobile Plus device is intended for facilitating communication for persons with disabilities. It is sold with the Windows Control software and its price is over twenty times higher than the Tobii camera. The devices have a built-in processor and owing to this they do not strain a computer with unnecessary calculations, which is important because laptops of the tablet type, which have low computing power, are usually used for AAC.

Table 1. A comparison of the devices used during testing

Evaluation criterion	Tobii EyeTracker 4C	Tobii Dynavox EyeMobile Plus
Appearance		
Maximum screen size	27 inches with proportions 16:9 30 inches with proportions 21:9	Tablet holder to 13 inches.
Working distance	50cm – 95 cm	45cm – 85cm
Working area	40 cm x 30 cm at a distance of 75cm	35 cm × 30 cm at a distance of 65cm
Operating system	Windows 7, 8.1 and 10 (only 64-bit)	Windows 7, 8.1 and 10 (only 64-bit)
System recommendations	2.0 GHz, Intel 5 or 7, 8 GB RAM memory	Dual-Core 2.0 GHz 4 GB RAM memory
Additional software	No	Windows Control
Built-in:	Mounting to a screen by adhesive tape and magnet.	Battery, charger,1x port USB, 2x port 3.5mm for buttons, two loudspeakers of power 3.5 W, tablet holder, infrared port
Price	About € 170	About € 4 300

Source: own elaboration.

The devices, whose basic characteristics are presented in Table 1, are characterised by similar functionalities, the same system limitations, and a similar working distance and area, that is to say the zone from which they are able to collect data about current eye position. The biggest difference is their appearance and the price for which you can buy the device. The TobiiEyeTracker 4C device is much cheaper and provides more possibilities in assembly. The TobiiDynavoxEyeMobile Plus, however, is intended only for tablets of up to 13 inches diagonal size, has a few additional solutions, such as e.g. its own battery, or loudspeakers or is sold with the Windows Control software which enables it to operate a computer by eyesight alone.

The eye tracking devices described in the latter part of the paper were used to conduct tests of performance and usability during daily work with a computer.

Testing the performance and usability of eye tracking devices

An analysis was made of sets (consisting of a device and software) that are used by persons with disabilities such as cerebral palsy, spinal muscular atrophy and other conditions in which motor and speech dysfunctions are impaired. For these persons, eyesight is the most important (and often the only) channel of communication which permits the subject to operate a computer. A purpose of testing was to indicate the optimum equipment and system configuration of an eye-tracking set after conducting performance and usability analysis. It has been assumed that the analysis made will show to what extent the sets (the dedicated device and the eye-tracking set with free software that is about 24 times cheaper) differ and which one allows satisfactory operation of a computer in the alternative communication mode.

Examination of performance of the equipment-program configuration.

In this study the research made use of automatic performance tests which permit data on the performance of the operating system to be collected during analysis of different equipment-program configurations.

The behaviour of applications and Internet services under different strain conditions and using different equipment-program configurations to simulate system operation was examined during testing.

The tests were made using a computer – a portable device, which – due to the specificity of the studies – had to meet requirements of the manufacturers of the eye trackers. It should be emphasised here that for the eye tracker to be user-friendly in alternative communication, it needs to be connected to a light portable computer with its own power source. The Microsoft Surface Pro Notebook was selected for the tests. Program PCMark 10 Basic Edition produced by Futuremark Corporation was used to check the notebook performance in different equipment and program configurations. The software in this version is free of charge and provides a great deal of information on the computer's performance. The tests carried out using the PCMark 10 program take about 35 minutes and include a wide range of operations, from daily operations performed on the computer to demanding work with digital media. The tests can be divided into three groups:

- Daily use tests
- Performance tests
- Multimedia creation tests.

Tasks in the group of 'daily use' tests check how a computer deals with regular use and include, among other activities, browsing the Internet, videoconferences and application start-up time. Tasks in the performance group check system usability in daily office applications, such as work on spreadsheets and opening, writing and editing documents in text programs. The last group is the creation of multimedia content and include the editing of images and videos, rendering and visualisation. The task of the activities above is to strain a system to collect detailed data. The result of the test carried out may vary depending on what equipment and program configuration is used. Data such as the start-up time of applications, programs or websites can be found in the responses. It is worth emphasising that the program performs the same set of tasks each time, and that is why, after a minor change in the equipment configuration, a change in the result can be expected. A test was conducted in nine equipment-program configurations in order to check how much eye trackers strain a computer:

- Notebook Microsoft Surface Pro connected to power with an activated Windows 10 Pro Operating System OS ([1])
- Configuration [1] with a connected and activated device TobiiEyeMobile Plus [2]
- Configuration [2] with activated computer control software for Windows Control [3]
- Configuration [2] with activated computer control software OptiKey [4]
- Configuration [2] with Microsoft's beta version activated computer control software Eye Control (Pointing with eyesight) [5]
- Configuration [1] connected to an activated TobiiEyeTracker 4C device [6]

- Configuration [6] with activated computer control software, Windows Control [7].
- Configuration [6] with activated computer control software, OptiKey [8]
- Configuration [6] with Microsoft's beta version activated computer control software Eye Control (Pointing with eyesight) produced by Microsoft [9].

Results

Those tests which present time in seconds needed to perform the specific operation were selected from the list of tests conducted and they are presented in Table 2.

Table 2. The results of the different equipment/program configurations (time in seconds needed to perform the specific operation)

Tested configurations	Starting a text application	Starting a graphics program (GIMP)	Starting a web browser	Loading a 3D object from the website of an online store	Opening a text document	Saving a text document	Adding a photo to a text document	Saving edited JPEG	Daily Use Tests	Performance Tests	Multimedia Creation Tests
Performance Test 1 OS	2,856	3,177	1,118	1,627	2,218	1,297	0,651	1,641	6561	5399	2259
Performance Test 2 OS	2,867	3,177	1,161	1,685	2,080	1,272	0,659	0,509	6597	5420	2361
Performance Test 3 OS	2,888	3,160	1,156	1,697	2,121	1,285	0,668	1,555	6594	5389	2360
Performance OS	2,870	3,171	1,145	1,670	2,140	1,285	0,659	1,235	6584	5403	2327
Test 1 OS +EyeMobile	2,825	3,284	1,176	1,711	2,179	1,296	0,667	2,300	6550	5253	1752
Test 2 OS+EyeMobile	2,998	3,496	1,280	1,872	2,148	1,350	0,700	2,161	6166	5100	1181

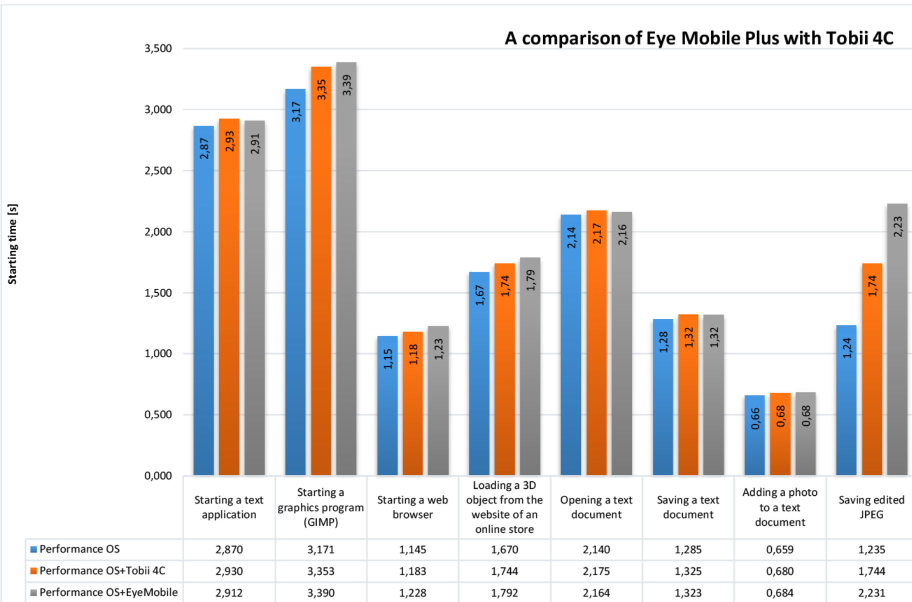
Performance OS+EyeMobile	2,912	3,390	1,228	1,792	2,164	1,323	0,684	2,231	6358	5177	1467
Test 1 EyeMobile +WindowsControl	3,118	3,721	1,319	1,988	2,486	1,404	0,719	2,013	6005	4381	1782
Test 2 EyeMobile +WindowsControl	3,069	3,724	1,346	1,847	2,330	1,633	0,765	3,210	5997	4235	1292
Performance OS+ EyeMobile +WindowsControl	3,094	3,723	1,333	1,918	2,408	1,519	0,742	2,612	6001	4308	1537
Test 1 EyeMobile +OptiKey	2,874	3,367	1,256	1,763	2,276	1,321	0,674	1,632	6433	5129	1822
Test 2 EyeMobile +OptiKey	3,003	3,588	1,269	1,951	2,225	1,429	0,757	2,858	5921	4208	1444
Performance OS+ EyeMobile +OptiKey	2,939	3,478	1,263	1,857	2,251	1,375	0,716	2,245	6177	4668,5	1633
Test 1 EyeMobile +*Eye Control* Microsoft	2,950	3,350	1,280	1,913	2,177	1,317	0,677	1,711	6258	4957	1833
Test 2 EyeMobile +*Eye Control* Microsoft	3,047	3,568	1,294	1,769	2,163	1,463	0,740	3,154	6037	4435	1264
Performance OS+ EyeMobile +*Eye Control* Microsoft	2,999	3,459	1,287	1,841	2,170	1,390	0,709	2,433	6147,5	4696	1548,5
Test 1 OS+ Tobii 4C	2,968	3,400	1,202	1,770	2,201	1,335	0,683	1,770	6448	5279	2088
Test 2 OS+ Tobii 4C	2,892	3,306	1,163	1,718	2,148	1,314	0,677	1,718	6448	5326	2152
Performance OS+ Tobii 4C	2,930	3,353	1,183	1,744	2,175	1,325	0,680	1,744	6448	5302,5	2120
Test 1 Tobii 4C +WindowsControl	3,057	3,576	1,267	1,804	2,196	1,387	0,700	1,824	6081	5142	2050
Test 2 Tobii 4C +WindowsControl	2,943	3,489	1,313	1,799	2,164	1,346	0,692	1,910	6210	5234	2055
Performance OS+ Tobii 4C +WindowsControl	3,000	3,533	1,290	1,802	2,180	1,367	0,696	1,867	6145,5	5188	2052,5
Test 1 Tobii 4C +OptiKey	3,020	3,495	1,246	1,757	2,200	1,331	0,671	1,735	6288	5280	2173
Test 2 Tobii 4C +OptiKey	2,904	3,373	1,187	1,798	2,181	1,311	0,693	1,769	6438	5232	2099

Performance OS+ Tobii 4C +OptiKey	2,962	3,434	1,217	1,778	2,191	1,321	0,682	1,752	6363	5256	2136
Test 1 Tobii 4C +*Eye Control* Microsoft	3,069	3,449	1,260	1,767	2,166	1,321	0,676	1,821	6333	5269	2182
Test 2 Tobii 4C +*Eye Control* Microsoft	2,940	3,342	1,208	1,734	2,225	1,362	0,703	1,886	6379	5195	2065
Performance OS+ Tobii 4C +*Eye Control* Microsoft	3,005	3,396	1,234	1,751	2,196	1,342	0,690	1,854	6356	5232	2123,5

Source: own elaboration.

Fig. 1 was prepared in order to compare the performance of particular configurations. It presents the initial performance of the system and changes after connecting the eye trackers.

Figure 1. A comparison of Eye Mobile Plus with Tobii 4C



Source: own elaboration.

When analysing the data it was noticed that the EyeMobile Plus device with the Windows Control software put the greatest strain on the computer's capabilities. It can be also concluded that the cheaper Tobii EyeTracker 4C device with free OptiKey software slows down the system to a small extent, although the differences are relatively small.

Table 3 presents the overall points that the particular configuration obtained in the performance test.

Table 3. Percentage calculation of OS strain for particular equipment/program configurations

Configurations / Performance test results	Result	Result [%]	% OS strain SO
Operating system performance (OS)	3124	100,0	*
Performance OS + Tobii 4C	2989	95,7	4,3
Performance OS + Tobii 4C + OptiKey	2974	95,2	4,8
Performance OS + Tobii 4C + Eye Control in Windows	2963	94,8	5,2
Performance OS + Tobii 4C + Windows Control	2889	92,5	7,5
Performance OS + EyeMobile Plus	2601	83,3	16,7
Performance OS + EyeMobile Plus + OptiKey	2552	81,7	18,3
Performance OS + EyeMobile Plus + Eye Control in Windows	2537	81,2	18,8
Performance OS + EyeMobile Plus + Windows Control	2440	78,1	21,9

Source: own elaboration.

The result of the test on the operating system unstrained by an application or a device is treated as 100% performance, and each subsequent change in the configuration results in a decrease. An analysis of the data in the table shows that it is enough to connect the device to the EyeMobile Plus eye tracker to decrease the performance of a computer by about 16.7%, which, taken together with the relatively weak computer performance of notebooks, can be problematic. The Tobii EyeTracker 4C device the computer performance by about 4.3% which is about one quarter the decrease of the EyeMobile Plus. From the measurement data it can be seen that the OptiKey program operating with Tobii 4C strains a computer to a small extent, about 0.5%. The OptiKey result when used with Eye Mobile Plus is slightly higher at about 1.6% and the difference between the Windows Control software and OptiKey is about 3%, whether or not we use one or other of the eye trackers. It is worth noting here that the performance test was only conducted with the devices connected and applications activated and it may differ depending on how programs are used and the extent to which eye trackers have to perform work to provide information about the current eye position to a computer. As mentioned above, for complete knowledge about the usefulness of the devices and their application in AAC, the usability of these configurations in everyday computer use should also be checked in addition to performance.

Evaluation of the usability of the devices and software

In the usability test, 15-year-old Wiktor, who is someone with multiple disability (being diagnosed with quadriplegic cerebral palsy with speech impairment since birth), and who uses AAC for daily communication, took part in the usability test. Owing to the Tobii company having put the first eye tracker for gamers on sale at a price of about 180 euro in 2015, his AAC set was significantly updated. In combination with the OptiKey software made available on the GitHub hosting service, which was in the testing phase, Wiktor's adventure with full computer support began. However, this solution used an eye tracker named EyeX which only operated using a 3.0 USB port and this put significant strain on the computer as it did not have a built-in processor for calculations. The above limitations forced the use of a desktop computer. It was only in 2017 that Wiktor began to use the Tobii 4C device, still with the OptiKey software, but already with a portable computer. In the meantime Microsoft's option for control using eyesight using Eye Mobile Plus has been used since the second half of 2018, as it required the accumulation of the appropriate sum to purchase the complete equipment. Fig.2. shows Wiktor using the set for alternative communication.

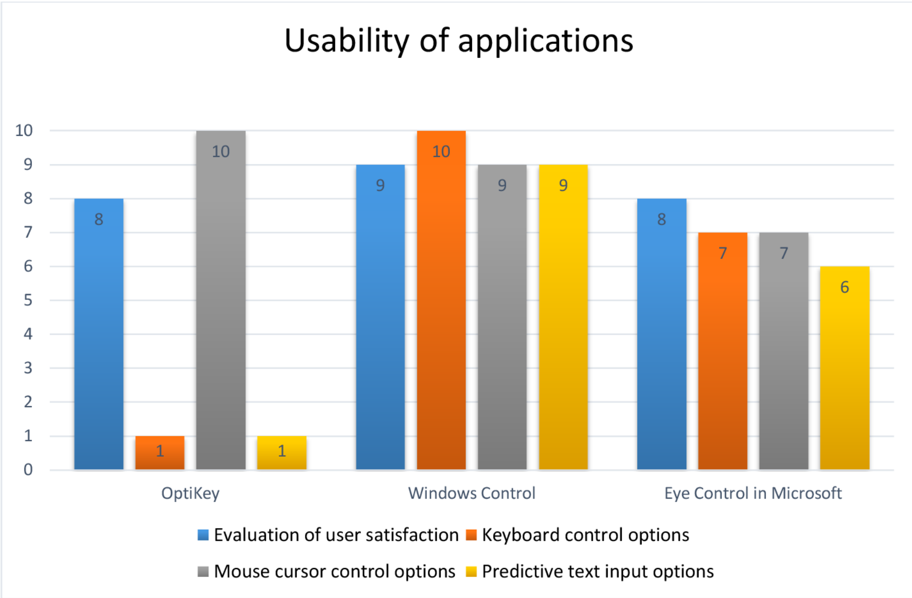
Despite the fact that Wiktor is only 15 years old, many firms dealing with communication aids have willingly tested different devices and solutions on him. Considering the experience gained, Wiktor is an appropriate person to comment on the configurations he has tested. As noted earlier, he is a person who uses the programs discussed in this paper every day and he also had the opportunity of using both eye trackers described. For an evaluation of the usability of the device and the software using the sense of sight for communication, a survey questionnaire was prepared and this was presented to Wiktor.

Figure 2. Wiktor – alternative communication using eye tracking

Source: own elaboration.

Wiktor received the survey on his private e-mail, opened it, and filled it in himself (using the eye tracking set for this purpose). The assessment scale in the survey was from 1 to 10, where 1 was a very bad (low) score and 10 was very good. When Wiktor was asked about the Eye Mobile Plus and TobiiEyeTracker 4C devices, he assigned them grade 9 and 7, respectively. The high grade of EyeMobile Plus was caused by the fact that this device, unlike Tobii 4C, has many additional options such as: an integrated notebook holder, its own battery and loudspeaker or an infrared port which can serve as a remote control. Wiktor stated that the greatest common fault of those devices was the fact that they both operated poorly or did not work at all when operating under sunlight. An additional section of the survey dealt with programs which were used by Wiktor. The results (including the assessment scores) are presented in Fig. 3.

Figure 3. The usability evaluation application on the basis of Wiktor's opinion



Source: own elaboration.

As can be seen in Fig. 3, the OptiKey, Windows Control and Eye Control (Indicating with Eyesight) Microsoft applications were the subject of evaluation. The assessment included such criteria as an assessment of satisfaction using the application, assessments of the keyboard, mouse control and text prediction options. According to Wiktor, the Windows Control program should be given the highest score, followed by Eye Control Microsoft and finally OptiKey. However, it should be emphasised here that if one observes the way that Wiktor works on the computer, it can be noted that he changes the programs that he launches depending on what he needs to do at the moment he starts the program and uses the option that will perform best in the specific task. Wiktor also indicated that the program Eye Control Microsoft allowed rapid calibration. In his opinion this is an option that is very much needed as the accuracy of indicating elements on the screen decreases if one changes position in front of the computer.

Additionally, it is known from the results of the survey that according to Wiktor, the Windows Control program has the best developed keyboard and mouse control option, it can predict words which he wants to write on the keyboard at that moment very well, it has the most options to increase comfort in using the application and facilitate better personalisation, and most important, it is the best program for operating the BoardMaker application (a communication program using tables and signs).

Eye Control Microsoft is simplest to operate, most precise and has quick access to saying the words entered which significantly speeds up communication.

The next program analysed is OptiKey, used for the first time by Wiktor in 2016, now refined and having all the options needed to operate a computer using the sense of sight. According to Wiktor, this is the only program which could replace the other two.

Installation, configuration and calibration of the devices and software in question

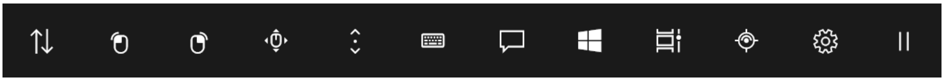
Installation of the TobiiEyeTracker4C device is very simple; one simply has to connect it to a computer. Then, the Windows 10 system, if connected to a network, finds the device drivers, and if not, Tobii software available on the *https://gaming.tobii.com/getstarted/* website should be downloaded. The program installation is intuitive. Next, it is enough to place the device in a proper location, turn on the calibration and follow instructions.

Calibration is similar for both the devices in question, with the difference that Eye Mobile Plus is delivered with the Windows Control application and all the drivers and software that are required are installed automatically.

Installation of the OptiKey software is also intuitive, it is enough to activate a setup program and follow the guidelines.

The only problem can be the activation of the indicating-by-eyesight option provided by Microsoft. In order to activate this option an eye tracker must be connected to the computer, then you must go to the *ustawienia (settings)* option > *ułatwienia dostępu (accessibility)*> *sterowanie wzrokiem (eyesight control)* and enable this option. A transparent bar should appear on the screen (Fig. 4). It can be operated both by mouse and by eyesight.

Figure 4. ***Eye Control*** **(Indicating with eyesight) Microsoft**



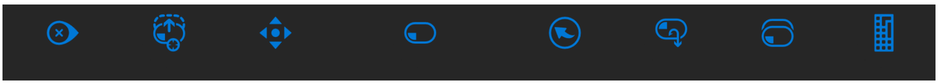
Source: own elaboration.

The appearance of the OptiKey (Fig. 5) and Windows Control (Fig. 6) applications is presented below for comparison.

Figure 5. OptiKey

Source: own elaboration.

Figure 6.Windows Control



Source: own elaboration.

The programs for operating a computer by eyesight work in a similar way. The solutions used, e.g. while selecting or using a chosen option, are the source of the greatest differences. It should be emphasised that operating a computer by eyesight takes much more time than classical methods of selection such as a mouse and a keyboard. This is caused by the fact that in order to activate e.g. a web browser a user must focus his/her eyes on the option for a moment (click the left mouse button twice), and then he/she must look at the icon for the web browser on which he/she must focus his/her eyes for a moment to activate the double-click option. During work the user must stay focused on one point; he/she cannot look chaotically around the computer screen.

Longer practice with these programs can speed up work with a computer by decreasing the focus time for selecting a specific option. This can be take place by default because a user begins to act intuitively and he/she does not think about which option he/she should select at this moment.

Conclusions

On basis of the analysis of the performance and usability tests that were carried out on the selected equipment-program configurations, it can be concluded that eye trackers together with the appropriate software provide almost problem free operations on a computer at present, both for everyday use, internet browsing or operating computers for alternative communication. It is worth noting that the performance tests showed slight strain of the system – from 5% to 20%. Considering that the devices were used in combination with a portable computer of average performance at this moment, this is a satisfactory result. Furthermore, the opinion of the user using only the sense of sight to operate a computer allows one to state that at present this technique is a solution which can help many people with disabilities restricting communication with their surroundings and provide relatively free use of different applications (including educational ones), network services, while also providing normal use of a computer.

The results of the tests conducted show that the optimum equipment and system configuration for the eye tracking set for AAC is use of the EyeMobile Plus equipment configuration offered by the Tobii company in combination with the Windows Control application and a portable computer of a tablet type. It should also be concluded that a cheaper eye tracker in combination with free applications gives a satisfactory result and can certainly be used as a valuable aid in AAC.

Many difficulties were encountered while writing this paper, the main problem being to find a research group. We wanted the testing of particular configurations to not be based solely on the performance test, but be complemented with the opinion of users. Reaching a greater number of individuals with complex disabilities in which communication was only possible by eyesight and who have experience of the use of different eye trackers and interactive applications turned out to be very difficult. The majority of people whom we reached have just started to use an eye tracker, investing in expensive solutions from Tobii Dynavox. Nobody except Wiktor had tried a cheaper solution „for gamers" to operate a computer. Considering the above, usability tests could only be made with his help. However, it should be noted that each configuration was tested for a long time (since 2016) and for this reason Wiktor's opinion, expressed in the form of assessments of particular devices and applications, can be considered sufficient. It is worth mentioning that during one of his recent stays in a rehabilitation centre, he helped the carer of one of the children there to install and configure an eye tracker system based on his practical experience and the knowledge he possesses.

References

1. Al-Rahayfeh A., Faezipour M. *Eye Tracking and Head Movement Detection: A State-of-Art Survey*, "IEEE Journal of Translational Engineering in Health and Medicine" 1/2013, 11-22.
2. Arias E., López G., Quesada L., Guerrero L., *Alternative and Augmentative Communication for People with Disabilities and Language Problems: An Eye Gaze Tracking Approach*. In: Di Bucchianico G., Kercher P. (Eds.) *Advances in Design for Inclusion. Advances in Intelligent Systems and Computing*. Vol 500, 2016, Springer, Cham.
3. Chen, S.K., O'leary, M., *Eye Gaze 101: What Speech-Language Pathologists Should Know About Selecting Eye Gaze Augmentative and Alternative Communication Systems*, "Perspectives of the ASHA Special Interest Groups", 3/2018, 24-32.
4. Clarke, M., Price, K., *Augmentative and alternative communication for children with cerebral palsy*, "Paediatrics and Child Health", 22(9)/2012, 367–371.
5. Dalmaijer, E.S., Mathôt, S., Van der Stigchel, S., PyGaze: *An open-source, cross-platform toolbox for minimal-effort programming of eyetracking experiments*, "Behavior Research Methods", 46(4)/2014, 913–921.
6. Duchowski, A. T., *Eye Tracking Methodology, Theory and Practice*, Third Edition. Springer International Publishing AG, 2017.
7. Gillespie-Smith, K., Fletcher-Watson, S., *Designing AAC Systems for Children with Autism: Evidence from Eye Tracking Research*, "Augmentative and Alternative Communication", 30(2)/2014, 160-171.
8. Holmqvist, E., Thunberg, G., Dahlstrand, M. P., *Gazecontrolled communication technology for children with severe multiple disabilities: Parents and professionals' perception of gains, obstacles, and prerequisites*, "Assistive Technology", 30(4)/2017, 201-208.
9. Ibrahim, S., Vasalou, A., Clarke, M., *Design Opportunities for AAC and Children with Severe Speech and Physical Impairments*. In: Mandryk, R. and Hancock, M. and Perry, M. Cox, A, (Eds.) CHI '18: Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems. Association for Computing Machinery (ACM): New York, NY, USA, 2018.
10. Kelway, J. J., Brock, A. M., Guitton, P., Millet, A., Nakata, Y., *Improving the Academic Inclusion of a Student with Special Needs at University*

Bordeaux. Proceedings of the 20th International ACM SIGACCESS Conference on Computers and Accessibility – ASSETS ’18, 2018.

11. Lancioni, G., O’Reilly, M., Singh, N., Sigafoos, J., Boccasini, A., La Martire, M., Perilli, V., Spagnuolo, C., *Technology to support positive occupational engagement and communication in persons with multiple disabilities,* “International Journal on Disability and Human Development”, 15(1)/2016, 111–116.
12. Light, J., McNaughton, D., Caron, J., *New and emerging AAC technology supports for children with complex communication needs and their communication partners: State of the science and future research directions*, “Augmentative and Alternative Communication”, 35(1)/219, 26-41.
13. McBride, D., *AAC Evaluations and New Mobile Technologies: Asking and Answering the Right Questions*, “Perspectives on Augmentative and Alternative Communication”, 20(1)/2011, 9-16.
14. McNaughton, D., Bryen, D. N. (2007). AAC technologies to enhance participation and access to meaningful societal roles for adolescents and adults with developmental disabilities who require AAC. *Augmentative and Alternative Communication*, 23(3), 217–229.
15. *Get started with eye control in Windows 10* (2020). https://support.microsoft.com/pl-pl/help/4043921/windows-10-get-started-eye-control.
16. *Surface Pro tech specs* (2020). https://www.microsoft.com/en-us/surface/devices/surface-pro/tech-specs.
17. Mitra S., Palmer M., Kim H., Mont D., Groce N. *Extra costs of living with a disability: A review and agenda for research*, “*Disability and Health Journal*”, 10(4)/2017, 475-484.
18. Myrden, A., Schudlo, L., Weyand, S., Zeyl, T., Chau, T., *Trends in Communicative Access Solutions for Children With Cerebral Palsy,* “Journal of Child Neurology”, 29(8)/2014, 1108–1118.
19. OptiKey – Help and Support (2020). http://www.optikey.org/help/what-is-optikey.
20. Santella, A., DeCarlo, D., *Robust clustering of eye movement recordings for quantification of visual interest*. Proceedings of the Eye Tracking Research and Applications Symposium on Eye Tracking Research and Applications – ETRA’2004.
21. Stolińska, A., Adrzejewska, M., *Eye-tracking indicators of emotions during problem solving*, “Journal of Modern Science”, 3(34)/2017, 181–196.
22. Vazquez-Li, J., Pierson Stachecki, L., Magee, J., *Eye-Gaze With Predictive Link Following Improves Accessibility as a Mouse Pointing Interface.*

Proceedings of the 18th International ACM SIGACCESS Conference on Computers and Accessibility – ASSETS '16, 2016.

23. Vessoyan, K., Steckle, G., Easton, B., Nichols, M., Mok Siu, V., McDougall J., *Using eye-tracking technology for communication in Rett syndrome: perceptions of impact,* "Augmentative and Alternative Communication, 34(3)/2018, 1-12.
24. Von Tetzchner S., Martinsen H., *Introduction to Augmentative and Alternative Communication*, Wiley, 2006.
25. Wilkinson, K. M., and Mitchell, T., *Eye Tracking Research to Answer Questions about Augmentative and Alternative Communication Assessment and Intervention*, "Augmentative and Alternative Communication", 30(2)/2014, 106–119.
26. *Windows Control Software* (2020). https://www.tobiidynavox.com/software/windows-software/windows-control-software/.