Evaluation of the Use of Eye and Head Movements for Mouse-like Functions by Using IOM Device

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Abstract. This paper describes a process of assistive technology evaluation using the eye and head movements as a CHI - Computer Human Interaction. In order to collect the data, it was used the Glasses Mouse Interface (IOM - Interface Óculos Mouse), device in development at the Federal Institute of Science, Education and Technology (IFSUL) which has been evaluated according to principles of user experience and usability testing.

Keywords: Accessibility · Assistive technologies · Computer human interaction · Glasses mouse · Assistive technologies evaluation

1 Introduction

People with disabilities generally do not have the same access to health care, education and employment opportunities. It is known that, very often, they do not receive the support they need, and end up experiencing the taste of exclusion to perform their daily activities. Analyzing the overall rates of people with disabilities, it is possible to perceive that social inclusion of minorities is not a simple task. One of these daily activities is the use of information technology. Although it can be considered a basic activity, for a population that is affected by a motor disability, the search for technological means enabling access to computer use, it becomes a necessity, especially in educational institutions.

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The problem arises when access to technological resources is denied due to the high cost. Several initiatives, in many areas of knowledge, try to adopt the full use of various computer tools for people with motor disabilities through the use of what is called assistive technologies (ATs), which allow accessibility and inclusion of users with those needs.

There are already many projects involving different areas of knowledge developing new applications of Computer Human Interaction (CHI) on Assistive Technologies.

A kind of project in this area regards to the creation of Interface Glasses-Mouse called IOM [19] in the South Riograndense Federal Institute at Pelotas (RS). Such device aims to allow the use of the computer by people with motor paralysis (without compromised intellectual capacity), including the use of Information and Communication Technologies (ICTs), to control the mouse movements through the head the movement and the action of mouse click, by the blinking of the eyes. The project is still under development of its features. In the other hand, it is already patented, having ready and tested prototypes for its posterior industrialization. That will enable an affordable lower cost device when compared to many existent devices with the similar purpose.

To validate the development of the IOM project a systematic mapping of assistive technology for the same purpose is required, mainly to enable the user with motor disabilitiesto manipulate graphical computer interfaces. The purpose of this mapping is to understand the state of the art in this scenario and confirm that the research is moving in the right direction.

The tests of User eXperience (UX) and usability evaluation have also been implemented and are aimed, through the analysis of their results, to generate inputs in how to establish the interaction of this device with these interfaces, describing difficulties and opportunities for improvement of the IOM project.

2 Glasses Mouse Interface (IOM - Interface Óculos Mouse)

The IOM system, represented in Fig. 1, is composed by a glasses with two sensors (gyroscope and accelerometer) that allow people use head and eyes movements to control the computer tasks. The IOM enables an alternative interaction style to mouse and keyboard controls. Hence, such solution can be very useful for users to perform hands-free control tasks.

This device is characterized as glasses that, may or not, contain the ocular lenses, according to the user needs. It basically presents two types of sensors which are responsible for the capture of voluntary eye blinking, the positioning, and inclination of the head. According to the user's motor disability, software control routines, such as calibration of inertial position and cursor speed, may be adapted by the user using the computer interface device to increase the comfort and performance.

Besides making possible the interaction with the computer hands-free, other goals of the IOM project is to develop a low-cost, lightweight and comfortable assistive technology. At this purpose we use prototypes in preliminary design stage to evaluate their performance according to these requirements.

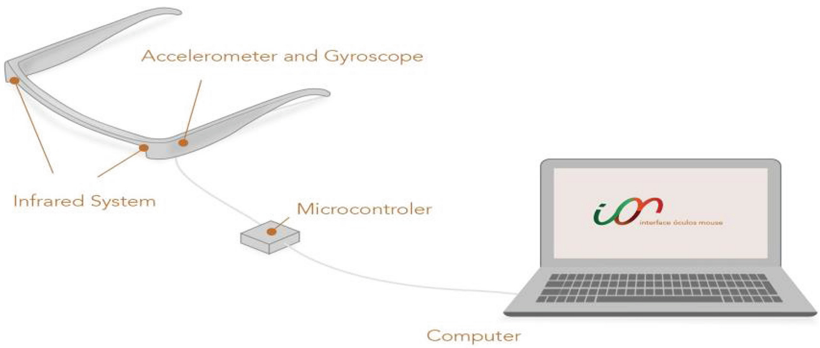

Fig. 1. The structure of IOM System

3 Related Works

Several projects in HCI area are under development or have already been developed in order to facilitate and enable users with disabilities to access the computer, as shown in Table 1.

Some examples of these devices are switches, joysticks and pointing devices activated by the body movements; computer screen vitual keyboard simulator softwares; speech recognition systems; eye movement controlled by computer vision systems; devices that control head movements; and more sophisticated devices employing the electric potential of the brain using EEG signals - electroencephalography, signals received by the eye movements using EOG - electrooculography [4] or contraction signals of voluntary muscles using EMG - electromyography [12] and even interfaces controlled by the brain, and brain-computer interface (BCI) together with a combination of brain sensors [3].

The detection of head movements can be done through video cameras, defined as video-based or camera-based, or by a device attached to the head with sensors that capture these movements, called head-based or head-track. Other motion capture method, is the face monitoring, which detects the region of the nose and mouth to control the mouse pointer. Alternatively, eye tracking (eye-based or gaze tracking) positions the mouse cursor at the estimated position of the user's eyes.

Eye tracking interfaces obtained even better performance than the traditional mouse (hand motion) in the speed aspect, however, the accuracy of current eye trackers is not sufficient for a satisfactory pointing in real time [6]. In [6], it proposed a more than one movement use technique to capture the cursor movement, head movement and eye tracking, called HMAGIC (Head Movement And Gaze Input Cascaded Pointing). The mouse pointer is activated by the direction of gaze and head movements the user makes for fine-tuning. The idea is to combine the advantages of speed of eye movements with the precision of the head movements.

Other related works use the camera-mouse software [23] to capture movements of the head, by recognizing the face and using the user nose as a central point. In [1] was added a feature to the camera-mouse to avoid accidental clicks, a pop up window allows the user to confirm the click, if it is inside a period of time that you can not be sure that you really wanted click the object in focus.

An overview of these assistive technology devices in CHI for motor disability users was made, like a comparative table, using as a tool the systematic mapping, show in Table 1.

Table 1. Assistive Technologies to mouse control for users with motor disabilities

Assistive technology	Movements	Ref.	Based	Tests with people with motor disabilities	Evaluation methods	System description
Click Control	Interacts with another pointer controller. Uses the camera mouse	[1]	video-based an gesture-based	yes, one student with cerebral palsy	User eXperience observation, a type of communicability as well.	Prevents accidental clicks (involuntary movements) through a screen to cancel the click. Can work with any mouse controller system.
User Tracking	face (head, nose, eyes and mouth)	[2]	video-based (remote - kinect sensors)	No	Usability (task-oriented) measurement time, precision and comfort	Natural movements using kinect in recognition of the face, eyes, nose, mouth (open, closed) and diferents sounds to click.
HMagic	head and eyes	[6]	video-based + eye track	No	Usability and UX	Cascading eye movements (speed) + head movements for precision
Tongue drive	tongue	[7]	movements based	yes	Usability	This system consists of a headset that transmits (wireless) data captured by sensors on the user's mouth. Managing to capture the rotary movements of the tongue.
AsTeRICS	head and speech (adaptive)	[8]	video-based	yes	Usability and UX	Adjustable platform depending on the user's disability. Web Cam + Plug in, facial recognition.
Snap Clutch	eye tracking captured by Tobii X120 and implemented by Tobii SDK	[9]	eye-based	yes	Task-Oriented, Usability (OS 9241-9) and Fitts Law interface, and think-loud technique.	Move the eyes to pointer control in games. For entertainment purpose.
Mouth switch	Head and mouth	[10]	video-based	no	Task-Oriented, Usability	Detects the head and mouth movements both vertically and horizontally

(*Continued*)

Table 1. (*Continued*)

Assistive technology	Movements	Ref.	Based	Tests with people with motor disabilities	Evaluation methods	System description
Eye-Gaze	eyes	[13]	Gaze-tracking - oculography	yes	Task-Oriented, Usability and UX	Hardware to be used in parallel with the mouse.
2D cursor-to-target	voluntary contraction of facial muscles	[12]	Capture face signals muscles (sEMG)	no	UC, Davis IRB Protocol 200513697-3. Usability	Two EMG sensors capture two muscles of the face to be the X and Y coordinates on the screen
Wiimote	head and speech	[14]	head-tracking pointer and speech	–	–	Windows API, the WiiLab and also the SAPI (speech recognition) and software that includes the Wii and Glasses LED control (IR) and captures the head movements
Camera Mouse	face (head, nose, mouth and eyes)	[23]	video-based, face track	yes	Task-Oriented, Usability and UX	Capture of the head movements to move and stop at certain objects to select time (dwell click).
FaceMouse	nose	[26]	video-based	yes	UX	Capture the face image and uses the nose as a reference for pointing on the screen
Head-Tracking Pointer (HTP)	head	[27, 28]	video-based	yes	Task-Oriented, Usability	Head movement to control the cursor
Blink and wink Detection	head and eye blink	[29]	video-based	No	Usability and precision tests	Head movements to control and blink to click
Haptic Glove Leap Motion	captures hand movements	[15]	gesture-based	No	UX	Device is like a glove that captures hand movements. Uses the Leap Motion.
The Eyebrow Switch	eyebrow	[16]	video-based	Noo	UX	Device that checks the movement of the eyebrow, works like pointer.
Head Track	head	[30]	video-based	No	Usability	Device that captures the movement of the head through a web cam
Head tracking, and the virtual keyboard interface	face	[18]	video-based	yes	Usability	Used in mobile devices, captures the image with a camera and an overlay keyboard image, where the user can see more clearly where the nose points.

4 Evaluation Methodology

Many tests have been applied, as a way to quantify and qualify the IOM User eXperience in relation to its control of the GUI (Graphic User Interface). A qualitative approach, in order to evaluate the device's UX and usability with oriented tasks, resulted in the quantitative data analysis for continual improvement of the IOM. Although the project focuses on the development of AT for people with motor disabilities, it was decided at that time to apply the tests in typical users (without restricted mobility). This is done due to the fact that when we test this device directly with people with motor disabilities, it generates an expectation of immediate use of a product that is still in its initial development cycle. These users get high expectations that can influence the evaluation of aspects of UX, while the typical users are completely "disengaged" and without risk of frustration.

It was also considered that the feedback from a typical user, with respect to IOM's user experience, will be approximated in basic concepts of cognitive ergonomics and the utilization of the tool in computer use will approximate the user with motor disabilities since the tests there is a restriction only use the IOM as CHI device without any other apparatus. According to Brade [20], the test of driving process follows the steps below, which were used in evaluation methods: Test planning, Organization of material, Local preparation, Pilot test, Choice of users, Test driving, Result analysis. The intended audience for the evaluation tests was composed by students of the institution and the operating system used in the test (Microsoft Windows) for activities development. As explained before, the intention was not to assess the IOM interface specifically for disabled users (despite the central bias of the project predict that) but the general public, and this may give general contributions that are useful for the use of IOM in a specific context. If we think of features that include people with motor disabilities to use the IOM would have two most common usage scenarios. The first one would be the use at home, in different postural positions, some of which can compromise the efficiency of the usability testing and operation of the device (e.g. a lying person using computer). Another scenario, which was planned for the tests environment, it was the classroom environment, or work location in which through the IOM would be possible to include this user in a real scenario with accessibility purposes education and work, for example. We have opted for this second condition by the ease of using the actual project development educational environment. For verification in terms of usability, it was applied a script of predefined tasks consisting in a user interaction with some graphic elements arranged in the interface. This script was explained in real time to users at the moment of development of tasks, and to complete a task was revealed the next step. Uptake of these tasks listed below where the time interval was quantify between each of the tasks as well as the errors made (clicking in an inappropriate spot for example) using the formula: **time in seconds / wrong clicks**.

List of WIMP (Windows Icons Menus and pointers) tasks:

1. Click on the icon (open file manager); 2. Clicking on an icon (maximize window); 3. Make a scrolling (scroll to the bottom of the screen); 4. Clicking on an icon to open ".doc" file; 5. Clicking on an icon to changing tools tab; 6. Clicking on an icon to close

software; 7. Clicking on an icon to open file manager menu; 8. Clicking on an icon to close file manager.

The listed tasks generate quantitative data, the time of the task execution was logged by the video recording, whereby it is possible to identify some usage patterns and constant errors in the use of IOM in which usability becomes evident. In order to qualifying the user experience we apply our observations in the records recorded on video, aind in which bodily expressions and audios were collected about IOM use. It were also applied two questionnaires, one focused on the general perception of use and the the other focused use of the AttrakDiff [21] online tool which generates a User eXperience chart from opposite pairs of adjectives attributed by users to the tested device.

5 Results and Discuss

A total of 9 volunteers, 3 women and 6 men aged between 18 and 45 years, were recruited in IFSUL - campus Pelotas to develop planned tests which were applied. Most of them were students and had never used any device or eye movements based software and head pointer control in the GUI. Half of them uses glasses for visual disability and almost use the mouse as the primary interaction tool with the computer. As the testing protocol already established, at first the typical users made a routine tasks with the common mouse and then using the IOM device. This whole routine was recorded in both the GUI and through facial and body registration of users. They were also asked to answer a use experience questionnaire. Some ergonomic aspects were raised in this questionnaire about the IOM's usage on a possible fatigue generated by its use in the eyes and overall comfort.

Some of results about the questionnaire applied of the users:

- Most users stated that the use of IOM caused a little eye fatigue, or no fatigue;
- In relation to the neck comfort, which needs to be moved to control the pointer on the GUI through the IOM, three users felt a moderate to high fatigue.
- About general physical effort the data also points for most users with low or no fatigue. Only two users reported a moderate to high fatigue, which was confirmed by good comfort appointed by a majority of IOM users;
- In addition to the ergonomic aspects that generate important axes of analysis, especially regarding the IOM design principles, the functional aspects of the same interaction with the computer were answered by users, who, in general, indicated that their difficulties and overall experience of use IOM. Most users indicated difficulties both in the control of the mouse pointer's movement speed and the accuracy of the same as the charts below.

This qualitative analyse about questionnaire is confirmed as shown in Table 2, average time of tasks development in usability testing, which demonstrated the highest time spent with the IOM and the recurring errors to perform each of the tasks regarding the use of the mouse.

Table 2. Average times in the tasks in seconds /total errors numbers

User average	1	2	3	4	5	6	7	Average/errors
Mouse	3.8/1	5.3/0	4.2/0	4.3/0	5.7/1	4.6/0	2.8/0	31/4
IOM	13/1	29.5/3	19.7/2	33/1	23.4/3	54.6/14	19.6/2	186.7/24

In general terms the average time for development tasks using the traditional mouse is around 17 % faster than with the IOM. Although comparatively the mouse as a device that allowed greater flexibility (smaller tasks runtime) and a lower error rate in the context of this research, the majority of users indicated a satisfactory user experience with the IOM regarding the first use of it.

6 Discussion

Through the comparative Table 1 of systematic mapping, we can see that several studies show the use of the head and eyes movements as good techniques to be used as a control in HCI devices, especially considering the scenario of assistive technology focused on people with motor disabilities.

Even the capture of eye movements have less physical movement of the heads movements, still this movements have spent less physical effort than the employee to move arms or hands. However the results of usability evaluation with the IOM were significantly worse than the average mouse which leads us to consider some aspects. One hypothesis is that the learning curve for users, when faced to a new device, is larger, requiring of the user more time to use the same to get more consistent comparative results of IOM in relation to the mouse that is already widely used. We will require new testing devices that actually use this same technique of interaction to establish standards for more calibrated comparisons according to the device rated in the issue in here, just like as those ones listed in systematic mapping. These tests must also follow more specific protocols and be refined as established by Morimoto [6] whereby the tabulated data have higher accuracy, and this method already applied in tests with some other devices such as the Camera Mouse [4], which allows a good degree of comparison.

We evaluated the implementation of Communicability Evaluation Method (CEM), or the think loud method, on the tests and this has not established a direct relationship with the aim of testing since our goal was not to assess semantic aspects of graphic elements of the interface, but the usability and user experience with the IOM device. In terms of user experience, these tests showed that users found some difficulty in evaluating this new device because it has characteristics of objects reference (glasses and mouse) used in a new context of use, like HCI device. The estrangement in the use of this should be evaluated as normal if we consider that this new apparatus has no other similar already widespread, which makes it a product with innovative features to intended audience of people with motor disabilities. Through a questionnaire AttrakDiff tool was qualified friendly and attractive as the IOM is. The results show how the IOM is a desirable and self-oriented device.

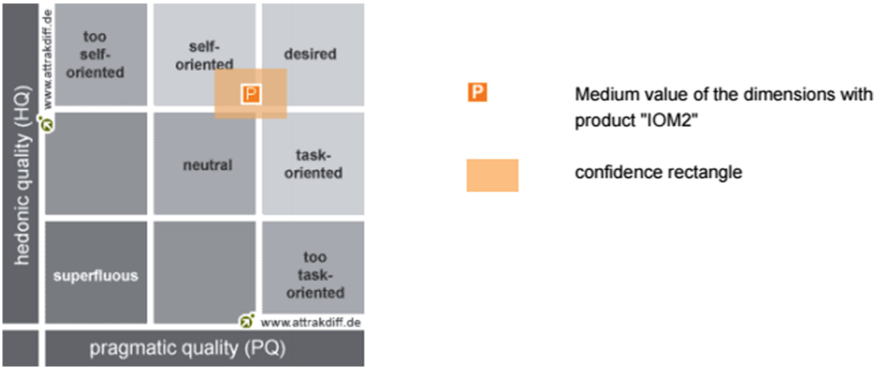

Fig. 2. Evaluation use generator perceived by IOM (Color figure online)

7 AttrakDiff Tool

In Fig. 2 the axis of the average value of the product dimensions is well on the threshold between self-directed and desirable product. There is, therefore, the interpretation of these results, the perception of space for development both in terms of usability as in hedonic quality. The user is clearly stimulated by the product, but it is at least this power valence threshold, and you can say the same regarding the perception that the product gives to self-solve. The results of usability tests confirms the need of improvement of the IOM especially in some specific points such as: cursor movement speed control; accuracy and the the click itself controlled by eye blinks presented some usability issues. Suggestions collected by users and implementation for group perceptions by IOM and its testing compared to other devices with the same purpose (some of which are already being implemented software): control from the head movement speed; implementation of graphical interface element that facilitates the control on the accuracy of the click; new click control modes, such as longer blink or time without moving the cursor to activate the action. For further work is necessary to apply new tests with these protocols and an increasing systematization of the results of the IOM compared to other assistive technologies that use the same principle of interaction, in order to generate a final product more enjoyable and usable by users with motor disabilities.

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