Research: What Eyes and Brain Reveals about Visual Performance in the Curved Display

Eglė Radvilė, Antanas Čenys

Faculty of Fundamental Sciences, VGTU, Sauletekio al. 11,
Vilnius, Lithuania
{Egle.Radvile, Antanas.Cenys}@vgtu.lt

Abstract. Fitts law is a basic for every end user system. The software design made by thousands of rules is orientated into task execution time. More and more people are using two displays for daily work, sometime curve monitors and rules of software design for that is not the same as for the flat screen. In article we are analyzing Fitts law formula adaptation that could be used in a curve display. Data that was taken researching 2 - 4 years children by electroencephalography signals to investigate the following issues, using the time – frequency representations method, for each epoch corresponding to one presentation. Study experimental paradigms to understand simples of fits' law for interpretable readable signals. Also during this study was showed weakness of hardware. The silent purpose of this research was to empirically compare the visual performance between flat and curved displays.

Keywords: Children brain waves, usability, curved display, brain waves, system psychology, interface motivation, user/machine system, and software psychology.

1 Introduction

The research is attributed the direction of future trends: information brains, eyes information for natural user interface design and user experience by using it (business, people and systems interoperability). In line with this trend looks at the individual elements featured which can have affects different users with software operations. Increasing technological development, the manufacturers launch more and more screens of various sizes and shapes. The curved displays have been introduced to the market since 2014 and are available for each user as providing astonishing experience and allowing a wider field of vision. The main benefit for which the curved display is known is that the distance between the user and the edges of the screen is much less than the flat display, providing an increased area in the user's peripheral vision. The main benefit for which the curved display is known is that the distance between the user and the edges of the screen is much less than the flat display, providing an increased area available in the user's peripheral vision). Especially, when it comes to large screens, the users need to use physical navigation (e.g. eye, head and body movements) in order to avoid external – edge visual distortion. In the curved display, however, the entire screen surface is expected to be equidistant from the viewer's eyes, allowing less physical navigation without any loss of detail.

Therefore, we believe that "Good" or "comfortable" for user experience is directly related to physical parameters and user psychological behavior. Accordingly, the following research questions is proposed:

R1: What Brain are "thinking" when you are using comfortable and not comfortable application? When it is comfortable?

R2: Where Eyes are looking if it is comfortable and not comfortable ... and flat... and curved

R3: Do eyes tracking hardware really show us curved pointing situation of background?

Clear and accurate answers to these questions would be a revolution in application design field. Results could be a descriptions of the rules that even unfamiliar with technology person could very well oriented-and very quickly perform the tasks. However, accurate answers are purely hypothetical and more like a goal in the future, which step by step will be achieved. The largest contribution of this paper are two experiments: Fitts law element dependencies, and the curved display screen measurement calibration evaluation.

For now there is still very little empirical comparison of user experience and visual performance between flat and curved displays. Thus, the present study aims to evaluate the effect of the curved display on visual performance and user experience. Finally, this study can help manufacturers to understand strengths and weaknesses of various forms of imaging, providing effective guidelines of visual communication through the curved display. During all paper and experiments, the primary role is dedicated for Fitts law.

Fitt's law is a descriptive model of human movement primarily used in human–computer interaction and ergonomics. This scientific law predicts that the time required to rapidly move to a target area is a function of the ratio between the distance to the target and the width of the target. Presented [14] in formula 1:

$$t = a + b \cdot \log_2(ID). \tag{1}$$

Here t is the mean time to hit the center of a target and constants a and b are estimated from a particular experiment. Constant a is called the non-informational part or reaction time. Constant b is the informational part in seconds per bit or a slope. Their distance from start point to the center of the target is called amplitude A while the tolerance of the jump is called width W (radius or width of the target). ID is the index of difficulty:

$$ID = \frac{2 \cdot A}{W}. \tag{2}$$

There were multiple experiments with Fitts' law, when it was adapted to different Human Computer Interaction (HCI) devices [15]–[20].

To achieve the above stated aims and answering research questions the paper is organized as follows. The subsequent section deals with the review of key literature from the studied fields. Based on this review the papers third section presents a new approach for monitoring and evaluating the deployment of understanding user experience using simple design set by Fitts law. These experiments are the different way trying to understand the speed and quality of app used by user in daily work. In the papers fourth section the results of the study. The fifth section discusses the key results from the perspective of the paper's research questions and concludes the paper. The sixth section – ideas and plan for future work.

2 Related Works

The design of system usability is a very complicated, multidimensional task. According to J. Nielsen [1] system usability aims to identify problematic places rather than to find universal rules for perfect system design. This is highlighted by other authors [2]–[8]. In these papers ergonomic properties of various systems are analyzed ergonomic properties of various systems are analyzed and specific recommendations provided. It is pointed out that the usability is strongly dependent on user's properties as well. In the standard of the International Organization for Standardization and the International Electro technical Commission ISO/IEC 9126-1, 2001 [9], software quality is divided into seven main categories with one called "Quality in Use" as described in part 4 [10] and depending on the system's user properties.

One of metrics in this standard is Task time (*Ta*) - how long does it take to complete a task. Task type and complexity can vary depending of the type of the system; however the most common task in an information system is to find some information or even to notice some information on the user interface (UI). It takes time to move the eye gaze from one point in the UI to another and just then certain actions are done to finish the task. The eye gaze movement as a usability characteristic is important as current tendencies implies the eye movement can be used as input device instead of mouse or other device [16]–[17]. Therefore eye gave movement could be used for complex UI task execution rather than visual search only.

The eye gaze movement time depends on a particular user, however range of possible values can be estimated in advance. Fitts law can be used to estimate part of the task execution time depending on information search on UI since it defines how the movement time from one point to another depends on the target size and distance [11]. Therefore if we know the target size and anticipated user eye gaze movement speed we can estimate how long user would take to get to the object from different places of the UI. Therefore Fitts law can be used to optimize user eye movement time from one object to another by changing objects size or place in the UI.

Reviewing the relevant works has been observed that Fitts law has two parameters a and b that are almost not examined and usually counted as constants. In some materials may find explanation on their calculation, but more or less it is a hand muscle tension and double click. So we start finding the same elements not for hand but for the eyes and their dependence on curved screen settings.

3 EXPERIMENTS: Brain and Eyes vs Curved and Flat

To understand how end users are feeling using software is not that same as to understand why they are feeling so. As it was mentioned before, this experiment is one of three parts of research and is more complicated than others. First of course children, even if we decided to call them kids (2 – 4 years) or exposed group [9] of human. This group require the most extensive adaptation of usability testing because their attention span, their motivation to please adults, and their ability to adjust to strange surroundings, things, and new people may change from moment to the next. In general, children in this age range should to explore the computer according to their own interests and pacing instead of performing a series of direct tasks. Eye will often be happy to show you what they know, and what they can do on the computer independently. When assessing appeal or engagement, testers will need to closely observe children‘s behavior such as sighing, smiling, or sliding under the table. Children this age often have difficulty expressing their likes and dislikes in words. [10]. Why exposed group was selected? They are clear from perfect information or information noise [12].

3.1 Ethics and Law

In 2014 April Lithuanian Bioethics Committee gave their consent to the study, which was done using special EEG, Eyes Motion tracker and Video hardware and software for 2 – 4 years children. The Committee decided that the measures are compatible with research for children's rights and is not forbidden. Each child participating in the experiment was with his mom or dad in the common room, feeling safe and calm. To ensure that the reproduction of your illustrations is of a reasonable quality, we advise against the use of shading. The contrast should be as pronounced as possible.

3.2 Participants and Stuff

We recruited fourteen participants, as Microsoft recommendation for usability testing experience with children [10]: used single-monitor with special software („M(n)“), and large curve monitor with special software(L(n)). All participants used computers more than one per week, but not more than 20 min per day. According to our pre experiment questionnaire, their daily/weekly computing activities were Youtube movies, mostly scenario „Masha i Medvedev“. The study was conducted in a locked office lab to ensure privacy. Each participant received present upon the compensation of the study. We chose not experienced users as we wanted to see how their interaction and visualization understanding can be view on brain wave log.

For study we had two extra stuff persons and moderator. One was responsible for logging track (special software, brain wave software, eyes tracker software, video for study), other for prepare EEG headphone, pre experiment questionnaire and activity log, last one for talking with children about what they should do.

Most attempts to understand usability and lucky user experience with continuous EEG measurements work by monitoring Beta and Gama, because people cannot learn to change the amplitude of these two waves by making the appropriate mental effort or by raising his or her level of attention. By the fact in experiment, all frequencies were logged.

3.3 Software and Hardware

For exactly this experiments was taken one computer monitor 17“ Philips, also one curved monitor 54.6" Measured Diagonally OLED Samsung, both 1920x1080 resolution. Place from participant to monitor was as recommendation [9-10] Fov, Horopter. Special software and design created by Fitts law recommendation created with Pascal Lazarus 1.2.2. For brain waves monitoring was taken („Brain computer interface technology“) EPOC Emotive, Mind workstation, Brain Computer Interface and Scientific desktop hardware and software.

Three sessions was done using Neurosky Mindwave hardware and software.

For Eyes tracker (eyes reaction) Mirametrix and viewer software Mirametrix research conform to the Eye – gaze Interface. The Open Eye-gaze Interface provides a standardized method for performing calibration and acquiring eye-gaze information. The Open Eye-gaze Interface is based on a web services model for data transmissions. Communication is performed using a client / server architecture, passing XML.

3.4 Methods

The success of EEG signal analysis essentially relies on the quality and the relevance of the information extracted from raw records. This experiment presents the signal processing methods related with the aim of the work, the time – frequency methods of signal analysis, used for feature extraction. The traditional analysis tools we use for the analysis of stationary signals, such as the Fourier transform, are no longer adequate for the analysis of most non –stationary signals. Instead, Time – Frequency Representations (TFRs) are more suitable.

3.5 Positioning of observed circle

Two monitors of different width but of the same hight are combined in one system that displays an image at an angle not in a single plane. An additional computer and mirametrix equipment is used for calibration and eye movement fixation. When mirametrix calibration is turned on the second computer, analogical image (changing pictures) is displayed in screen system where the user has to look at an approriate point for calibration. There were also other ways but simplicity was selected

It is important to match screen systems and dimensions of the screen for calibration, as mirametrix software uses proportions of the screen, significant calibration errors are possible. After calibration the user was given the window through both screens where circles of similar size were depicted on the full screen of 64 columns and 21 rows. One of 1344 circles changed its colour from pale grey to red every two seconds; random number from 0 to 9 was depicted inside. The user was given a task to tell the number in that circle as quickly as possible. Relative coordinates (meanings from 0 to 1) of eye fixation were recorded by Mirametrix equipment, what time and where a depicted highlighted circle with a number on the screen (what column and row in) was fixated; a man performing an experiment was filming. Dimensions of the screen, resolutions, position by the user's approach are also measured (between the screens, user's distance to the angle of the curved displays). All this data was used for the accurate detection of the point of eye fixation position and time prediction required to move glance from one point of screen system to another. Each user carried out the same test three times during the experiment firstly eye movements were calibrated, and then 10 points in advance and 10 random points were shown to all the users every 2 seconds.

4 Additional Experiment and Results

Comparing how much measured values differ from real, it is received that while determining the column, the error is approximately 3, 29 width of the column (standard deviation 1, 34 width of the column) what the studied situation corresponds to 165 pixels. Meanwhile, determining the number of the row (comparing measured coordinates with shown point) an average error reaches 1, 20 width of the row (standard deviation 0, 78 width of the row) that is equivalent to 60 pixels of the hight of the studied screen system. The difference between the errors of the columns and rows is close to 3 times, what partly shows that the system is not appropriate for searching positions of determining an accurate point in the curved display systems.

Adjustment of coordinates of two screen systems (recalculation from a two-dimensional projection to the surface of the screen) was applied to adjustment of eye fixation, relative coordinates of eye position. Recalculating y coordinate of each point and converted into an appropriate circle visual column it is received that determining a column an error is 2, 30 width of the column (standard error 0, 79 width of the column). It shows that eye fixation point position after recalculation adjusted to one column or about 50 pixels of screen width.Setting of column standard deviation decreased that equalled to setting of column standard deviation. This indicates that the remaining errors are more related to measurement equipment, the errors during calibration, as accuracy of column setting does not depend on curved display systems.

It was also noted that detected and recalculated eye fixation point positions are deviated towards the centre of screen system. This distribution shows that detected coordinates of eye fixation point, expanding proportionally, it would be possible to improve accuracy of eye positioning. Furthermore, the difference of adjusted and detected coordinates depends on the angle of the screen in respect of the user and the distance of the observed point from the centre of screen system. Set by mirametrix equipment and checked by two monitor model system. The whole diagram shows overall layout of the screen and a blue line almost at the middle of the chart shows where intersection of the screens is, the angle between the screens. Figure 4

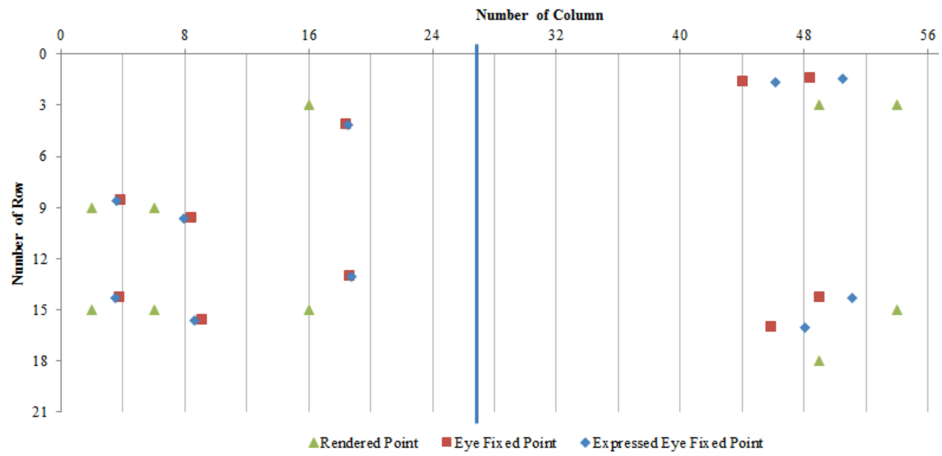

Fig. 1. Visual research: 3D compared with 2D (Mirametrix).

Calibration errors were quite big (100 and more) because of the unusual conditions of the test. The user's position in respect of the screen system is changeable and calibration repeated until the error will not exceed 100. An average fixed calibration error is 79, 5 (standard diversion 10, 9) during the study. Assessing accuracy of the user's vision, those coordinates of the points are taken from mirametrix eye fixation point magazine which are stabilized, that is, have 5 points and the coordinates range 0, 5 % of the screen area. To simplify comparison, all relative point coordinates converted into the column and row numbers of the circle. It allows comparing different distances from the screen or the angle of the screen. (not tied to specific distance measurement units).

5 Conclusion

Our experiment with different tasks, the motivation level can be identified according to the beta and gamma brainwave activity. The fact eye movement slope is significantly different in aimed and unnamed tasks, shows we decided correctly to indicate motivated tasks if the gamma brainwave increase is more than 2 Hz.

The motivation level is a big factor for eye movement *a and b* of 2 to 4 years old, as aimed objects are reached even up to 5 times faster by the eye comparing to unnamed tasks, where lack of motivation exists and overview method is sometimes used rather than straight look into one object.

One of the main limitations of this study is that since the number of trials is very low (and since the number of likes is very low for some subjects) the statistical power of their tests and generalizability of the results is limited. Further, the influence of type or nature of stimulus on the study also deserves attention. Also there could be some result threats of validity: variations of the physical conditions (altitude, distance to the screen, people, and sounds) can change results settings that will not be so clear, and will be the next part of the study.

Talking about inflection that could be important result understanding that curved line could be the reason for faster daily work and easier to use like slope (b) (in this case eyes slope). And we understood that for real results of eyes tracking hardware we should recalculate all results.

And after all there could be answers to research questions: R1: What Brain are "thinking" when you are using comfortable and not comfortable application? When it is comfortable? *Answer: There is no one law, single object or objects system as a whole, which is influenced by the speed (m/s) of the user's work (t), but is a motivation as stimulator that drives user this tasks to do faster. Then is comfortable then is faster?* R2: Where Eyes are looking if it is comfortable and not comfortable ... and flat... and curved. *Answer: comfortable or not answer R1. The curved screen – in a three-dimensional space (depends on target distance can be a two-dimensional projection).* R3: Do eyes tracking hardware really show us curved pointing situation of background? *Answer: No, we should recalculate.*

6 Future work

As our main project propose is to have real metrics of understanding what exactly BETA Hz and GAMA Hz diapason should be when user is feeling comfortable by using software made by NUI. The data (data cloud of Fitts law, Eyes tracking, Brain Waves, Curve monitors and so one) stream values are often associated with multiple aspects which can be modeled by a tensor or high order array. We hope our results will be a small detail reaching end user satisfaction.

References

1. Smith, T.F., Waterman, M.S.: Identification of Common Molecular Subsequences. J. Mol. Biol. 147, 195--197 (1981)
2. May, P., Ehrlich, H.C., Steinke, T.: ZIB Structure Prediction Pipeline: Composing a Complex Biological Workflow through Web Services. In: Nagel, W.E., Walter, W.V., Lehner, W. (eds.) Euro-Par 2006. LNCS, vol. 4128, pp. 1148--1158. Springer, Heidelberg (2006)
3. Foster, I., Kesselman, C.: The Grid: Blueprint for a New Computing Infrastructure. Morgan Kaufmann, San Francisco (1999)
4. Czajkowski, K., Fitzgerald, S., Foster, I., Kesselman, C.: Grid Information Services for Distributed Resource Sharing. In: 10th IEEE International Symposium on High Performance Distributed Computing, pp. 181--184. IEEE Press, New York (2001)
5. Foster, I., Kesselman, C., Nick, J., Tuecke, S.: The Physiology of the Grid: an Open Grid Services Architecture for Distributed Systems Integration. Technical report, Global Grid Forum (2002)
6. National Center for Biotechnology Information, http://www.ncbi.nlm.nih.gov