Improving the Design of Virtual Reality Headsets applying an Ergonomic Design Guideline

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Abstract

The aim of this project is to study the ergonomics of low-cost Virtual Reality (VR) headsets and improve their weak spots. An Ergonomic Design Guideline has been created to assist in the evaluation of current designs based on observation and user comments. This Guideline has been assessed by experts in VR from the Human-Computer Interaction Association (AIPO).

The methodology used is the Process of Usability and Accessibility Engineering model (MPIu+a), in which the user is the centre of the design process at all times. This model is iterative, repeating the cycle of requirement analysis, design, implementation, prototyping, evaluation and launch until a satisfactory result has been obtained.

Voluntary participants have assessed the quality of different VR headsets and have helped create an Ergonomic Design Guideline. Their insight has raised questions for further design improvements applied in the new headset, as well as validation of modifications made.

The final result is a cardboard headset, based on Easy Phone's Cardboard model but improving its ergonomics by modifying the design to satisfy the user's needs. This has reduced pain on cheekbones, nose and forehead significantly, and the general design is now more attractive to users. Further investigation will be necessary in order to solve the usability problems encountered when using Virtual Reality technology with these devices.

1. Introduction

The term Virtual Reality has existed since 1985, but it has not been until the past few years when it has started to attract the average user with the increased use of smartphones and videogames. Even so, today's Virtual Reality (VR) devices still have improvements to be made to ameliorate their ergonomics. Dizziness, vertigo and an increase in perspiration are some of the symptoms reported by users, as well as pain on the head and face due to unsatisfactory subjection system designs.

This project aims to improve the use of low-cost VR headsets and create an Ergonomic Design Guideline for future designs. These devices have a huge potential amongst all types of users, with many applications that have not yet been discovered. Its improvement would translate in an increase of users and value of VR.

Although there are many existing devices used for the practice of such technologies, this work is centred on low-cost headsets. These are supports for mobile phones compatible with VR apps, including a minimum of a set of lenses, a subjection system and a main body to place all the elements. This focus on a particular type of product eliminates most electronics involved in the use of VR applications and gives space for more ergonomics improvements on the final product. In this work, devices are considered as low-cost when the price is under €100.00. This range of prices allows for a wide variety of headsets to compare, study and improve.

The initial goal of the project was to analyse the problems encountered with the use of this technology, such as dizziness or vertigo, but during the initial phase of requirement search, it was noticed that the current designs had to be greatly improved in order to reduce feelings of pain or discomfort while wearing the headsets. This then became the new objective of the investigation, mainly focusing on the direct interaction of the device and the user's face.

2. Objectives

The objectives of this project are related to the improvement of the design of VR headsets. The first of them is to choose a VR headset to modify, which should score low in ergonomic design assessments with identifiable faults.

The second objective is to create a design Guideline which will, on the one hand, help improve VR headsets in design or re-design phases, and on the other hand, assist in the assessment of these devices. This Guideline should be easily applied on any VR headset, or it will not be useful for the evaluation of this kind of products.

Finally, the re-design of the headset has to score better than the original device in the user's perspective, in order to validate the Guideline and the design process. If it does not score better, it is important to study the re-designed version of the headset and analyse why it is scoring worse than the original product.

A secondary objective is to include application proposals for VR technology. It is important to justify each alternative with tests.

These objectives have to be completed by keeping the user at the centre of the design, and at all phases of the re-design process. This will ensure that the final product will be accepted by the user and that it will include the features that the user considers most important.

3. Methodology

Following the methodologies taught in various subjects in the Industrial Design Engineering studies, the user has always been at the centre of the design process. The main method used are interviews with different user profiles that offer enough information to proceed to the next task.

The first step for this project was to create a user requirements list, done by studying the target user. Firstly, a remote online questionnaire (answered by 86 people from different age groups) was carried out to understand who the users of VR technology are and what they are interested in.

The target user profile is a young person of up to 25 years old, with some interest in ages up to 59 years old. The gender of the user, in this case, is irrelevant, and they tend to have an interest in using VR technology for learning (40% in children from 0 to 12 years old and 74% in young people aged 13 to 25) and gaming (100% in children and 59% in youngsters). There is also an interest in watching films (80% in children and 56% in youngsters), and people aged 13 to 25 are also keen on live events (50%). The target user would not have any impairment in the use of VR headsets or VR technology.

Another technique used (Fig. 1. Original headsets comparison test) was an analysis of four different VR headset models (Fig. 2. Easy Phone's Cardboard Black, Fig. 3. Juguetrónica's VR Phone Glasses V2, Fig. 4. Samsung's Gear VR and Fig. 5. Woxter's NEO VR1) and comparing test participants' reactions to each of them. This was done with 16 Industrial Design Engineering students through an online questionnaire in an Interaction laboratory.

Fig. 1. *Original headsets comparison test*

Easy Phone's Cardboard Black was chosen based on low scores (average score of 1.9 out of 5.0) given by the users in this test. Participants who used this headset reported pain on the nose, on the cheekbones and on the forehead, as well as poor aesthetics. It was also claimed that the headset was incompatible with the use of glasses. An Ergonomic Design Guideline was then created based on the information collected.

Fig. 2. *Easy Phone's Cardboard Black*

Fig. 3. *Juguetrónica's VR Phone Glasses V2*

Fig. 4. *Samsung's Gear VR*

Fig. 5. *Woxter's NEO VR1*

The Ergonomic Design Guideline, which was still in process, was evaluated by nine VR experts from the *Asociación Interacción Persona-Ordenador* (Person-Computer Interaction Association, AIPO)[1]. These experts assessed a variety of commercial VR headsets using the Guideline and could then add any comments related to the questionnaire itself. It was discovered that even devices from a higher range of prices have aspects to be improved that have been detected with the use of this new design guideline.

Using it as a guide, four new design proposals were created, improving the current cardboard headset (Easy Phone's Cardboard Black). These were tested with 13 students from different Engineering studies, who assessed the changes made in an interview using the Ergonomic Design Guideline and a short comparison questionnaire. Amongst the compared headsets, one of them was the original Cardboard Black made out of the same material as the other options to avoid biases.

The results were statistically analysed with a Chi-squared test, in which the prototype with the best score was compared to the original headset. The compared heuristics from the Ergonomic Design Guideline were "7. The device rests comfortably on the nose" and "8. The device rests comfortably on the cheekbones". In both cases, there was a significant difference in scores between the two headsets (p-value = 0.025 for heuristic 7 and p-value = 0.027 for heuristic 8).

A final design proposal was tested through an interview with nine new participants (Fig. 6. Final prototypes comparison test) from different Engineering studies. This helped validate the new headset by comparing it to the best scored in the previous test.

Fig. 6. *Final prototypes comparison test*

They were asked to try the two prototypes and answer the Ergonomic Design Guideline in the form of an online questionnaire, a comparative short questionnaire and a System Usability Scale (SUS) questionnaire[2].

The new and final prototype scored better in all aspects (comfort on the nose, on the cheekbones and the forehead, a better subjection system and a better compatibility with the use of glasses). Still, the difference between the two was not as large as the one seen in the previous test, indicating that there are not many more improvements to be made in these compared aspects.

Other design tools have also been used throughout the project to aid in brainstorming, design and implementation phases, such as Quality-Function Deployment (QFD), eco-design, poka-yoke design or value analysis.

4. Design proposals

Based on the tests, new proposals were made. Each modification to the initial headset had a hypothesis linked to it, which would later on help assess the validity of each change in the design. These were the following:

- Increase the space for the nose (Fig. 7. Increase the space for the nose): This should make the headset less painful on the nose.

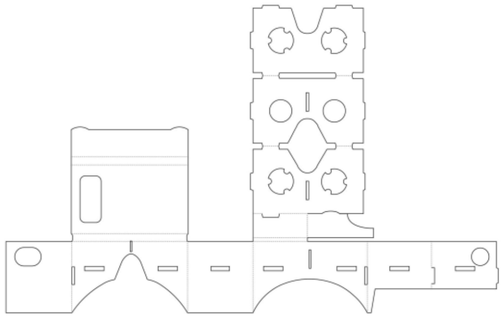

Fig. 7. *Increase the space for the nose*

- Increase the radius in contact with the forehead (Fig. 8. Increase the radius in contact with the forehead): This should help the device adapt to more types of faces and therefore reduce pain.

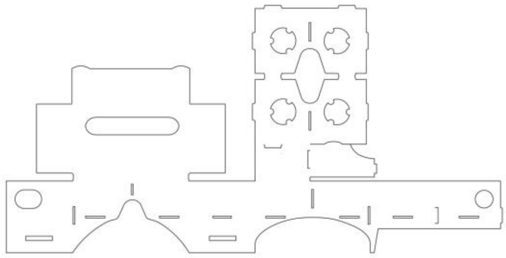

Fig. 8. *Increase the radius in contact with the forehead*

- Increase the radius in contact with the cheekbones (Fig. 9. Increase the radius in contact with the cheekbones): This should help the device adapt to more types of faces and therefore reduce pain.

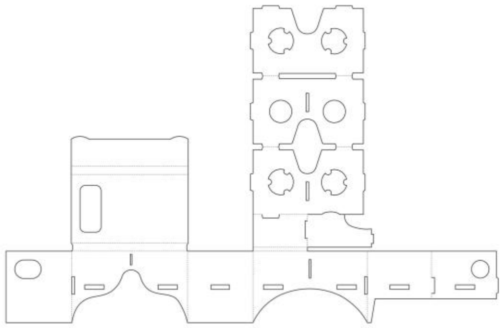

Fig. 9. *Increase the radius in contact with the cheekbones*

- Increase the space between the head and the device (Fig. 10. Increase the space between the head and the device): This should allow the user to wear glasses while wearing the headset.

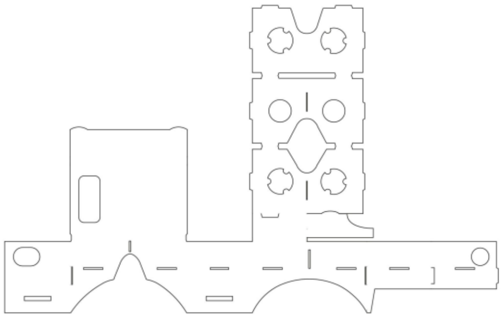

Fig. 10. *Increase the space between the head and the device*

- Increase the space on the sides between the head and the device (Fig. 11. Increase the space on the sides and add folds): This should allow the user to wear glasses while wearing the headset.
- Add folds on the forehead (Fig. 11. Increase the space on the sides and add folds): This should reduce pain on the forehead.
- Add folds on the nose (Fig. 11. Increase the space on the sides and add folds): This should reduce pain on the nose.
- Add folds on the cheekbones (Fig. 11. Increase the space on the sides and add folds): This should reduce pain on the cheekbones.

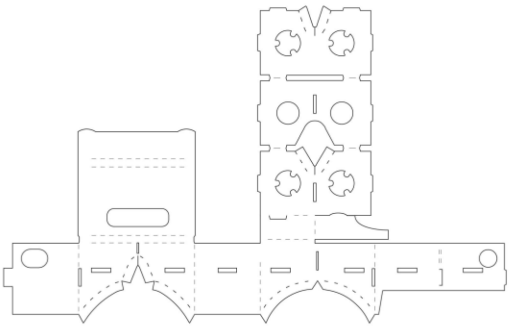

Fig. 11. *Increase the space on the sides and add folds*

These hypothesis were measured and some of them were more effective than others. The inclusion of folds in the design and the increased distances have proved to be the most effective changes in the design, which have been applied to the final prototype (Fig. 12. Final prototype).

Fig. 12. *Final prototype*

Finally, the visual identity was created for the headset and its hypothetical company. To do this, the steps followed were 1) to establish the values of the product's brand, 2) to create a symbol that represents these values, 3) to geometrise this symbol, 4) to choose a name based on the brand's values, 5) to choose a typography based on the brand's values, and 6) choose the colours based on the brand's values. These elements were then combined to create a final logo (Fig. 13. Final logo).

E-MOTION

Fig. 13. *Final logo*

7. Conclusions

The objectives of this project have been achieved, both primary and secondary goals. In the following list, the solution to each of the objectives stated at the beginning of the dissertation are explained.

- Choose a VR headset to modify: Easy Phone's Cardboard Black headset was chosen due to its low score in the benchmark and in user tests. It provoked pain on the nose, the forehead and the cheekbones, and was perceived as inexpensive and poorly designed. This was the right product to work on and improve.
- Create a design Guideline: The Ergonomic Design Guideline for VR headsets has been a critical aspect of this work. It is the interpretation of user comments through testing, and it analyses many aspects related to the ergonomics of these headsets. It has also provided information to re-design the chosen device with the right criteria and has helped in the assessment of different VR headsets. As a result, a preliminary

version of this project has been accepted at the 8th International Conference on Applied Human Factors and Ergonomics (AHFE) 2017.

- Re-design that scores better than the original headset: The re-design of the headset has scored significantly better in comparison tests with users, without them knowing that they were analysing and commenting on a commercialised product. This assessment has been done through the Ergonomic Design Guideline and through general questions that allowed for a comparison amongst different headsets. The results have been statistically analysed.
- Include application proposals for VR technology: Although no formal proposal has been made, user investigation shows that the most interesting applications for VR technology for the target group are education and live events. It is true that simulations of dangerous situations are currently being done to train professionals, but it could be and interesting idea to adapt this to other ways of learning. Live events in VR could make the user feel like he or she is there, and therefore these events could reach a much wider audience by the use of VR technologies.
- Keep the user at the centre of the design: One of the most important points of this work has been to keep the user at the centre of the design process at all times. Every change or proposal has been checked with users and are easily justifiable through this information.

5. Future work

Although the idea of this project was to create an investigation framework for ergonomics in VR headsets, many other aspects should be considered in future projects based on the same line of work.

Firstly, the Ergonomic Design Guideline should be revised. Some heuristics cannot be analysed equally by different people (i.e. Does long hair make subjection difficult?) due to physical differences. This makes the comparison of devices slightly biased and should be therefore used cautiously. Other questions cannot be answered using the same scale (the answer “yes” can be positive or negative depending on the question). There should be a way to present the different heuristics in a clear manner that still allows for the scale to be equal in each question of the Guideline.

Also, other design proposals should be made. Even though this project is not based on innovation, several improvements have been made on the original product. This, however, does not mean that they are final. Other solutions for adjustments should be discovered, such as the focal distance. The current design proposal for the distance between the lenses can also be further developed.

Finally, it is important for future studies to address the problems regarding the use of VR technologies. The minimum recommended distance between a mobile screen and the user’s eyes is much higher than the one used in these VR headsets. There are problems with dizziness and discomfort. The devices seem to remain uncomfortable for many users. All of these aspects should be analysed and solved for a correct product proposal to be made.

References

[1] Asociación Interacción Persona-Ordenador. [Consulted: 16 Jun 2017] Available at: <http://aipo.es/>

[2] Usability.org. System Usability Scale (SUS). [Consulted: 20 Jun 2017] Available at: <https://www.usability.gov/how-to-and-tools/methods/system-usability-scale.html>