Improving the Design of Virtual Reality Devices Applying an Ergonomics Guideline

Catalina Mariani and Pere Ponsa(✉)

Automatic Control Department, Technical School of Vilanova i la Geltrú, Av. Víctor Balaguer, 1, 08800 Vilanova i la Geltrú, Barcelona, Spain
catymariani@gmail.com, pedro.ponsa@upc.edu

Abstract. A methodology with the objective of evaluating the aesthetics and ergonomics of virtual reality glasses is presented. Many developers apply best practices taking into account hardware features, physiological considerations and interactive patterns that provide a safe and comfortable user experience. Usually, the user tests a virtual reality application in laboratory conditions. In this work, authors are paying attention to the first time that a user tries virtual reality glasses. In this initial phase, it is necessary to analyse the first impression considering the comfort of glasses on the face and head of the user. Using ergonomics principles, this work shows the creation of heuristics inside a guideline with the aim of improving the design of low-cost virtual reality glasses.

Keywords: Ergonomics · Virtual reality · Human-centred design

1 Introduction

Many researchers are using virtual reality to assess user experience [1]. These developers apply criteria (interaction, immersion and imagination) [2], best practices taking into account hardware features, physiological considerations and interactive patterns that provide a safe and comfortable user experience [3], Oculus Best practices [4], and Designing for Google Cardboard [5].

Direct involvement of users is a key factor in the human-centred design process [6]. The benefits of an HCD approach include increased satisfaction. For this reason, this work proposes to study the iteration of virtual reality glasses to entail the feedback of users following their use of early design systems [7].

Some researchers argue that dedicated headsets are required for true Virtual reality, and those makeshift devices that hold a smartphone close to the user's face fall short of providing a truly immersive virtual reality experience [8].

In this work, authors are paying attention to the first time that a user tries virtual reality glasses. In this initial phase, before the use of a virtual reality application, it is necessary to analyse the first impression considering the comfort of glasses on the face and head of the user. To sum up the method: Initial Test to evaluate aesthetics and ergonomics (Sect. 2), Build a set of Heuristics (Sect. 3), and VR Guideline (evaluation and re-design recommendations) (Sect. 4). Finally, conclusions and future lines are exposed.

F. Rebelo and M. Soares (eds.), *Advances in Ergonomics in Design*,
Advances in Intelligent Systems and Computing 588, DOI 10.1007/978-3-319-60582-1_2

2 Initial Test

The test was designed to evaluate the aesthetics and ergonomics of VR glasses. It consisted of a self-explanatory questionnaire and four VR glasses from different brands so that the user could compare them. This was carried out during a Human-System Interaction course on 2nd of December 2016, in the Design of Interactive Systems laboratory at the Technical School of Vilanova i la Geltrú.

The facilitator in this test was the first author of this paper (assisting the respondents during the test), with the support of the first author of this paper, who allowed it to take place during his class and who offered different sources of information to make the most out of the test.

2.1 Method

16 Industrial Design Engineering students taking the Person-Machine Interaction class were asked to voluntarily participate in the study. One by one, they were taken to the room in which the test was carried out, they were given a consent form (with an extra copy for them to keep) and asked to sit in order to fill in a Google Forms questionnaire. The four glasses were presented to them and they could then hold them and try them on to evaluate their design. These were:

- VR1: Easy Phone: Cardboard Black
- VR2: Woxter: Neo VR1
- VR3: Samsung: Gear VR
- VR4: Juguetrónica: VR Phone Glasses

The only intervention of the facilitator was when the respondent had any doubt in the way questions were asked or in recognizing which brand was which. After three tests, the questionnaires were answered by three students at once (without any contact between them) to optimise time.

The group of students who took the test were mostly men (56.3%). All respondents were within the age range of 21–31, classifying as young adults, and used either Android (68.8%) or iOS (31.3%) operating system on their smartphones. Most students (81.3%) had never used VR glasses before.

2.2 Findings and Recommendations

First impressions on Easy Phone Carboard Black: uncomfortable (sharp edges), light, too small for people wearing glasses, aesthetics (poor, simple, fragile), cheap.

First impressions on Woxter glasses: comfortable (foam), pain on cheekbones, good subjection, lighter than they look, too big, big enough for people wearing glasses, good aesthetics (Fig. 1).

First impressions on Samsung glasses: comfortable (foam, curves), good ergonomics, poor subjection, light, big, very good aesthetics.

Fig. 1. One user is trying to adjust the virtual reality glasses

First impressions on Juguetrónica glasses: comfortable (curves), pain on nose, good subjection, light, big, too small for people wearing glasses, functional (headphones), fragile.

2.3 Comparison

Samsung glasses are the most attractive device. Easy Phone Cardboard are the least favoured. From the point of view of the users, the Juguetrónica glasses look the most expensive and the Easy Phone Cardboard the cheapest.

Juguetrónica glasses are the heaviest and Easy Phone Cardboard are the lightest. Juguetrónica glasses are the most comfortable and the Easy Phone Cardbard are the most uncomfortable. The Table 1 shows the mean value (MV) and the standard deviation of the comfort assessment.

Table 1. How comfortable are the glasses? From a 5-point Likert Scale (from very uncomfortable 1 to very comfortable 5)

	VR1	VR2	VR3	VR4
MV	1	3,5	2,5	4,5
SD	0	*0,7*	0,7	0,7

2.4 Design of VR Glasses

When asked about the most important aspects in VR glasses design, the students considered that, in regards to form, these should take into account:

- Weight/size: they should be as small and light as possible to avoid balance problems
- Subjection to the head

- Accessibility: they should adapt to any kind of face (especially nose and eyes) and allow the user to wear regular glasses simultaneously
- Usability: intuitive access to buttons and other elements of the interface.

On function, the respondents had different points of focus, namely:

- Good immersion: good video quality, movement detection, sound, exterior isolation
- Easy to use: connectivity to devices
- Adjustability: both physical and virtually, without having to take off the glasses.

Use of VR technology.

Most respondents were unsure whether VR glasses can be useful or not, but some of the suggested applications were:

- Videogames
- Practicing different activities
- 3D modelling
- Shopping catalogues
- Visiting places virtually
- Films or videos.

3 Building a Set of Heuristics

The heuristics are classified into four features (glasses, subjection, face and control). The evaluation of the heuristics is qualitative (YES/NO) or quantitative (1/0). When the heuristic has a positive evaluation the quantitative assessment is 1. When possible, each heuristic has a re-design recommendation.

GLASSES[1]

H1 The device is compatible with the use of glasses.

When using glasses, the device can be comfortably placed.

[YES (1) NO (0)]

Recommendation 1: The designer can vary the VR device design to allow compatibility with glasses. If this is not possible, the user shall change the VR device until they find a compatible model.

SUBJECTION

H2 After the necessary adjustments, the device is well subjected.

The device is well subjected if it is not displaced when the user makes different movements while using it after correctly adjusting it.

[YES (1) NO (0)]

H3 When adjusting the device, long hair makes subjection difficult.

[1] Do not confuse the glasses of the user with the device "Virtual reality glasses".

Long hair might get tangled with the subjection elements when making adjustments, making this a difficult procedure.

[YES (0) NO (1)]

H4 The user needs assistance to adjust the device.

If the user needs assistance, they will take longer than what is considered normal when adjusting the device and will be quicker once assistance is given.

[YES (0) NO (1)]

H5 When adjusting the device, there is a noticeable change in the head's orientation.

The user might need to adopt an uncomfortable position to adjust the device.

[YES (0) NO (1)]

H6 After the necessary adjustments, there is a noticeable change in the head's orientation.

The user might need to adopt an uncomfortable position when using the device due to its weight or design.

[YES (0) NO (1)]

Recommendation 2: The designer must improve the subjection method (straps, Velcro, etc.) to prevent the device from being displaced when the user changes the head's orientation. These should also allow maximum adjustability for different types of people.

Recommendation 3: The designer should modify the device so that it is easily adjusted without assistance. If this is not possible, the designer should properly indicate that assistance is necessary when adjusting the VR device.

Recommendation 4: The designer must check the weight of the VR device if an uncomfortable posture is observed when adjusting or using it.

FACE

H7 The device rests comfortably on the nose.

The user might report some discomfort on the nose during or after using the device.

[YES (1) NO (0)]

H8 The device rests comfortably on the cheekbones.

The user might report some discomfort on the cheekbones during or after using the device.

[YES (1) NO (0)]

H9 The device leaves marks on the face.

The user might have noticeable marks on the face during or after using the device.

[YES (0) NO (1)]

H10 The device triggers a noticeable increase in sweat.

The user might show a noticeable increase in sweat during or after using the device.

[YES (0) NO (1)]

H11 The device triggers some type of pain on the back side of the head.

The user might report some discomfort on the back side of the head during or after using the device.

[YES (0) NO (1)]

Recommendation 5: The designer must check the mass distribution between subjection straps and the VR device's chassis to avoid overloading the nose and cheekbones.

Recommendation 6: The designer must check the device's materials (heat dissipation, refrigeration).

Recommendation 7: The designer must check the adjustment methods to avoid pain.

CONTROL

H12 The user can adjust the focal distance.

The device's design allows the user to adjust the focal distance.

[YES (1) NO (0)]

H13 (In the case of headphones) The user can adjust the distance between face and ears.

If the device has headphones, they can be adjusted to be comfortably used by the user.

[YES (1) NO (0)]

Recommendation 8: The designer must make control and adjustments easy for the user by the use of an instruction guide or adjustment buttons/mechanisms conveniently indicated.

4 Evaluation

From the point of view of the authors of this report, the obtaining and evaluation of VR heuristics allows us to create a VR guideline. The aim of this VR guideline is to assess the design of a VR device before the usability/user experience testing. The main question: How can a heuristic pass be evaluated in VR devices?

Authors have defined a Global_Index: all the heuristics have the same weight and the total number of heuristics is n = 13.

$$Global\_Index = \frac{\sum_1^i H_i w_i}{\sum_1^i H_i} \tag{1}$$

The first problem appears in the calculation of this Global_Index. The first criterion is that it is not possible to compare VR glasses with this method if the same heuristic list is not applied to all the VR glasses.

Heuristics 3–6 and 8–11 have not been assessed (NA) in the initial test. Heuristic 13 has only been assessed on Juguetrónica glasses because they are the only studied device that includes headphones. Thus, it is possible to apply a new heuristic list taking into account these criteria (applied only on the initial test presented in this paper):

- avoid the non-assessed heuristics for all the glasses evaluated
- avoid the Heuristic H8 (only measured for VR2 glasses)
- avoid the Heuristic H13 in this study (three out of four VR glasses don't have headphones)

With these criteria in mind, Table 2 is simplified into a new version, Table 3, where it is possible to compare results.

Table 2. List of heuristics (H) of the four VR glasses evaluated

H	VR3	VR2	VR1	VR4
1	1	1	0	0
2	1	1	0	1
3	NA	NA	NA	NA
4	NA	NA	NA	NA
5	NA	NA	NA	NA
6	NA	NA	NA	NA
7	1	0	0	0
8	NA	0	NA	NA
9	NA	NA	NA	NA
10	NA	NA	NA	NA
11	NA	NA	NA	NA
12	1	1	0	1
13				0

Table 3. Simplified list of heuristics (H) of the four VR glasses evaluated

H	VR3	VR2	VR1	VR4
1	1	1	0	0
2	1	1	0	1
7	1	0	0	0
12	1	1	0	1

Finally, the Global_Index is calculated from i = 1 to 4, w1 = w2 = w3 = w4 (Table 4).

Table 4. Simplified list of heuristics (H) of the four VR glasses evaluated

Global_Index	VR3	VR2	VR1	VR4
	1 (4/4)	0.75 (3/4)	0	0.5 (/4)

To sum up, the Global_Index allows the comparison between VR glasses (if the list of heuristics evaluated is the same for the VR glasses evaluated). The method does not show the calculation of the optimum VR glasses (it is out of the scope of this study, perhaps it is convenient to review the list of heuristics in more detail).

If the researcher is developing user testing in a laboratory analysing the performance and task effectiveness of VR applications and would choose a VR glasses model, the Global_Index could be useful because there are clear differences between the compared devices.

The designer could use the qualitative information to re-design the VR glasses with poor Global_Index. The qualitative information of the evaluated VR glasses is:

- **VR3 – Gear VR (Samsung):** Positive evaluation on 4 assessed heuristics. Users highlight comfortability and adjustment ease on face and head.
- **VR2 – Neo VR1 (Woxter):** Positive evaluation on 3 out of 4 assessed heuristics.

  Recommendation: The design must improve nose support, pointed out by several users. Placement on cheekbones should be minimised to avoid pain suffered by one of the users.
- **VR1 – Cardboard (Easy Phone):** Positive evaluation on 0 out of 4 assessed heuristics.

  Recommendation: The device is incompatible with the use of glasses. The device should be re-designed to allow this.
  Recommendation: The device is not well adjusted. The subjection method should be revised for its re-design.

  Recommendation: The device does not rest well on the nose. The device should be re-designed, adding foam for padding between the device and the user's face.
- **VR4 – VR Phone Glasses (Juguetrónica):** Positive evaluation on 2 out of 4 assessed heuristics.

  Recommendation: The device is incompatible with the use of glasses. The device should be re-designed to allow this. *Recommendation:* The device does not rest well on the nose. The device should be re-designed, adding foam for padding between the device and the user's face. *Recommendation:* The device allows distance adjustment between face and ears, but this personalization makes the global adjustment suffer. The re-design should allow a height adjustment for headphones.

5 Conclusions

It is well known that the use of a user-centred design approach improves the human performance [6]. When methods and tools from the human factors and ergonomics domain are applied, the result is a well-designed product, improving the performance and reducing the problems of use (mental effort or physical fatigue, for instance). In the context of use of virtual reality glasses it is necessary to search for best practices. Following the words of Oculus: *The practices are intended to help developers produce content that provides a safe and enjoyable consumer experience on Oculus hardware. Developers are responsible for ensuring their content conforms to all standards and industry best practices on safety and comfort, and for keeping abreast of all relevant scientific literature on these topics* [4]. The question is: Do all VR device developers have a document of best practices?

Google has a set of physiological considerations and interactive patterns for Google Cardboard VR devices [5]. For instance: head tracking, user control of movement, use of constant velocity, etc.

In this paper, a preliminary approach before the use of VR glasses is presented. An initial test with 16 users and research in the field allows authors to obtain data and information to develop a list of heuristics and a guideline for the ergonomics design of low-cost VR glasses.

The first results show that a VR guideline could be useful with the aim of choosing a VR glasses model taking into account, for instance, the perception of comfort.

An in-depth study is necessary with new VR glasses models to refine the guideline (improving the list of heuristics and the assessment method of the Global_Index).

Further research is necessary, for instance usability testing with VR applications, with the aim of measuring metrics (task effectiveness, efficiency, satisfaction, motion sickness) [9] and advancing in the comprehension of a good user experience [10].

Acknowledgements. This work was partially supported by the Spanish CICYT program under Grant TIN2016-81143-R.

References

1. Rebelo, F., Noriega, P., Duarte, E., Soares, M.: Using virtual reality to assess user experience. Hum. Factors **54**(6), 964–998 (2012)
2. Burdea, G.C., Coiffet, P.: Virtual Reality Technology, 2nd edn. Wiley, New York (2003)
3. Leap Motion: Ergonomics in VR design. http://blog.leapmotion.com/ergonomics-vr-design/. Accessed 27 Feb 2017 (2016)
4. Oculus: Documentation. Introduction to best practices. https://developer3.oculus.com/documentation/intro-vr/latest/concepts/bp_intro/. Accessed 7 Feb 2017 (2017)
5. Google: Designing for Google Cardboard. Physiological considerations. https://www.google.com/design/spec-vr/designing-for-google-cardboard/physiological-considerations.html. Accessed 27 Feb 2017 (2017)

6. ISO: ISO 9241-210:2010 Ergonomics of human system interaction – Part 201: Human-centred design for interactive systems. https://www.iso.org/standard/52075.html. Accessed 27 Feb 2017 (2017)
7. ISO: ISO/TR 16982:2002 Ergonomics of human system interaction – Usability methods supporting human-centred design (2017). https://www.iso.org/standard/31176.html
8. IAB: Is virtual the new reality? A karket snapshot of VR publishing and monetization. IIAB Report (2016). http://www.iab.com/wp-content/uploads/2016/09/IAB_VR_Report-Sep-2016.pdf
9. Kennedy, R.S., Lane, N.E., Berbaum, K.S., Lilienhal, M.G.: Simulator sickness questionnaire: an enhanced method for quantifying simulator sickness. Int. J. Aviat. Psychol. **3**(3), 203–220 (1993)
10. Riva, G., Mantovani, F., Capideville, C.S., Preziosa, A., Morganti, F., Villani, D., Gaggioli, A., Botella, C., Alcañiz, M.: Affective interactions using virtual reality: the link between presence and emotions. CyberPshycol. Behav. **10**(1), 45–56 (2007)

http://www.springer.com/978-3-319-60581-4

Advances in Ergonomics in Design
Proceedings of the AHFE 2017 International Conference on Ergonomics in Design, July 17–21, 2017, The Westin Bonaventure Hotel, Los Angeles, California, USA

Rebelo, F.; Soares, M. (Eds.)

2018, XX, 1040 p. 448 illus., Softcover
ISBN: 978-3-319-60581-4