Conference and Exhibition of the European Association of Virtual and Augmented Reality (2014)
G. Zachmann, J. Perret, and A. Amditis (Editors)

Feedback on in-flight applications of virtual reality to enhance comfort in future aircraft

Mirabelle D'Cruz, Harshada Patel, Laura Lewis, Sue Cobb

Human Factors Research Group, Faculty of Engineering, University of Nottingham, University Park, Nottingham, NG7 2RD, UK

Abstract

The European funded project VR-HYPERSPACE (FP7-AAT-2011-1-285681 www.vr-hyperspace.eu) has made great steps towards investigating innovative ways of using virtual reality (VR) and mixed reality (MR) in-flight, specifically to enhance passenger comfort in future air cabins. VR/MR were used to create virtual environments presenting "positive illusions" to a passenger either through head-mounted displays (HMDs) or large-scale displays. These illusions, based on research in virtual embodiment and space perception, were developed to investigate whether altering a person's virtual body, and placing a virtual body or your physical body in alternative environments, can change a person's perception of their comfort. This paper presents a brief summary of feedback from a group of VR-enthusiasts on the first demonstrations of these comfort illusions to the wider public.

Categories and Subject Descriptors: virtual reality, virtual environments, aviation, comfort

1. Introduction

The use of virtual reality (VR) and virtual environments (VEs) in the aviation and aerospace industries have been well documented (Regenbrecht et al. 2005; Stone et al. 2011). However, there are very few examples of the use of the technology while in-flight (apart from the potential for 3D games through personal devices brought onto the plane by passengers).

VR-HYPERSPACE (AAT-285681) was an ambitious €4.6M project funded under the European Commission's Seventh Framework Aeronautics and Air Transport (AAT) programme to investigate innovative ways of using virtual reality (VR) and mixed reality (MR) in-flight, specifically to enhance passenger comfort in future air cabins 2050 and beyond. This three year project (October, 2011 – September, 2014) consisted of nine internationally leading universities, research institutes and industrial partners from six European countries, exploring the use of VR/MR to create virtual environments presenting "positive illusions" to a passenger, either through head-mounted displays (HMDs) or large-scale displays. These illusions, based on research in virtual embodiment and space perception, were developed to investigate whether altering a person's virtual body, and placing a virtual body or your physical body in alternative environments, can change a person's perception of their comfort. This paper presents a brief summary of feedback from a survey conducted with a group of VR-enthusiasts on the first demonstrations of these comfort illusions to a wider public.

2. Method

2.1. Participants

A total of 58 participants were involved in this study, all drawn from attendees of the IEEEVR2014 (http://ieeevr.org/2014/) conference which took place in Minneapolis, Minnesota, 29th March - 2nd April, 2014 (D'Cruz et al, 2014). Due to the limitation in time available for participation, the number of participants varied for the five concepts being evaluated. All participants were self-selected volunteers - 42 were male, 3 female and 13 participants did not complete this question. Most of the participants (*n=25*) were aged between 26-35 years old with 8 younger participants aged between 18-25 years old and 7 older participants aged between 36-45 years old. Again, 13 participants did not respond to this question.

2.2. Equipment

Five VR-HYPERSPACE concepts used to create positive illusions of comfort were shown to participants, and are described below.

2.2.1. Changing the perception of self. The University of Barcelona (UB) investigated how altering the experience people have of their own body could induce the perception of being in a more relaxed state or even induce other states. For example, UB showed how using HMDs and self-avatars to embody a person in the attire of a musician could increase that person's feeling of "musicality" (Kilteni, Bergstrom and Slater (2013). In the current study, the participant wore an Oculus Rift HMD and was able to see their virtual body as a drummer in a virtual mirror with a first person perspective, as shown in Figure 1 below.

Figure 1: *Embodiment as a virtual drummer (UB, Spain)*

DOI: 10.2312/eurovr.20141345

2.2.2. Changing the perception of self and space. UB and the Max Planck Institute for Biological Cybernetics (MPG) used an Oculus Rift HMD and self-avatars to induce the perception of being in a more relaxed posture within a vast open space. MPG identified that environments such as tropical islands or sandy beaches were often used to describe "vastness" and wide open spaces (Mohler, 2013). In the VE developed by MPG, a flying carpet was used to alter the mode of transport from a plane and to provide a potentially "magical" experience while flying over a tropical beach. Gentle breezes were introduced in the experience to try and be consistent with any turbulence experienced in the real world, to make it less threatening and more acceptable to the passenger. Participants were able to see their virtual body in a first person perspective, with their legs stretched out in front of them while travelling on a flying carpet over tropical islands (see Figure 2 below).

Figure 2: *Flying on a magic carpet in a relaxed position (MPG, Germany)*

2.2.3. The Enhanced Airplane Cabin. The Fraunhofer IAO (FhG-IAO) and the University of Nottingham (UNott) explored the use of the cabin as a large display. Using the surfaces on the back of seats, surrounding panels and even the floor, and combining screens with spatial tracking of the head, it was possible to create a virtual window or transparent seat. This "enhanced cabin" could enrich the flight experience by displaying a view of the outside environment as you fly pass, and in the future enable the passenger to zoom in closer to points of interest. This extension of the flight experience was called, "Superhere". Alternatively, as the cabin is a display, the passenger could also choose to be in any other environment removed from the plane. This illusion was called, "Superthere" (see Figure 3 below). As the concept demonstrator was only installed at FhG-IAO in Germany, to present this to the participants in Minneapolis a video was viewed. In addition, the participant was able to see a cloud virtual environment using an Oculus Rift HMD. This was to demonstrate what it could feel like to travel in an "invisible plane".

Figure 3: *Demonstration of being on a tropical island while seated in a plane (copyright FhG-IAO)*

2.2.4. Social and Communal Spaces in the Airplane Cabin. The Bauhaus-Universität Weimar (BUW) explored the use of their multi-user, multi-viewer VR system to provide passengers with a shared view (from a first person perspective for all users) of environments and avatars so that co-located or remote groups of people could interact with each other to improve social comfort (Beck et al, 2013). As this concept demonstrator was only installed at BUW in Germany, a video was used to demonstrate to the participants in Minneapolis showing a number of opportunities enabled by this technology. For example, remote air crew or a virtual steward could be used to provide additional support on a plane; seat back displays could be expanded to enable other passengers to share the same view; and communal spaces could be created which enabled remote users on the ground or elsewhere to interact as part of work or leisure activities (see Figure 4 below).

Figure 4: *Passengers sharing a larger display and interacting with remote users on the ground (BUW, Germany)*

2.2.5. Inflight tele-operations on Mars. Thales Alenia Space Italia (TAS-I), the Institute of Communication and Computer Systems (ICCS) and the Technical Research Centre of Finland (VTT) explored the opportunities that passengers in the future could have for manipulating physical objects on the ground or even on a different planet while in transit. A remote visual monitoring system, posture recognition (to sense the position of a passenger's arm) and a data glove (to recognize gestures) was used to remotely control a robot arm as well as the overall movement of the Mars Rover. A video was used to present this concept to the participants (see Figure 5 below).

Figure 5: *The Mars Rover in a remote location being controlled by a participant in a study (TAS-I, Italy; ICCS, Greece; VTT, Finland)*

2.3. Procedure

ll the demonstrations and presentations for the five concepts were set up in the same space (as shown in Figure 6 below).

Figure 6: *Set-up of the demonstrations at IEEEVR2014*

The "illusion of self" and "illusion of self and space" were demonstrated using one Oculus Rift HMD set up. Another Oculus Rift HMD enabled the participants to view the clouds from the "enhanced cabin". A large monitor was placed in the middle of the space and was used to display the videos describing the "enhanced cabin", "social and communal spaces" and "inflight teleoperation" concepts.

A questionnaire was designed in the format of a consumer survey used to gather opinions on the VR-HYPERSPACE concepts. It consisted of two questions capturing demographics (gender and age), followed by five sections requiring feedback on the positive illusions created in the VR-HYPERSPACE project (described above). Each section included 7 – 9 questions depending on the concept, and they were a combination of rating scales, multiple-choice and open questions.

Participants were only able to take part in two or three of the five concepts due to time constraints. Each participant took around 5-10 minutes on each concept and they were able to ask questions throughout. After which they were given the questionnaire. On completion of the questionnaire, they received a VR-HYPERSPACE USB stick. The study received approval from The University of Nottingham Faculty of Engineering's Ethics Committee.

3. Results

3.1. Changing the perception of self

Twenty-nine participants experienced this demonstration. Seven questions were asked in total about this concept. The first asked participants to rate how much they liked the concept on a scale of 0-10 (with 0 being "don't like at all" to 10 being "like a lot"). The results are shown in Figure 7 below.

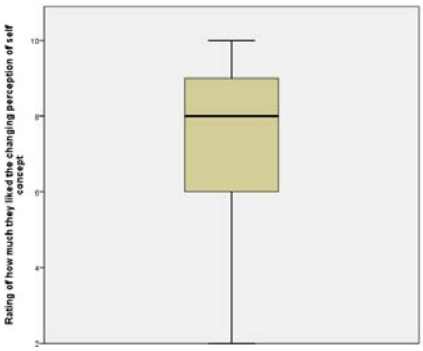

Figure 7: *Boxplot showing the ratings from 0-10 of how much the participants liked the "changing the perception of self" concept.*

Generally all the participants liked this concept with a median rating of 8 (IQR= 3). Thirteen participants said "yes" they would use this on a plane, 12 participants responded "maybe", with only two participants responding with "no" or "don't know". Similarly, 12 participants said "yes" and 13 participants said "maybe" it would enhance their flight experience, with three participants responding "no" and one participant responding "don't know".

With regards to the maximum the participants were willing to pay for this service on the plane, the results are shown in Figure 8 below.

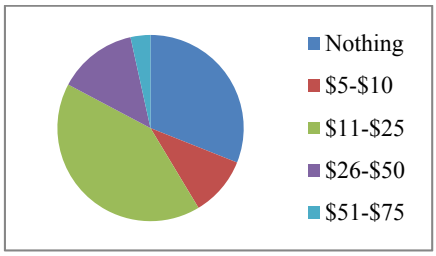

Figure 8: *Maximum amount participants were willing to pay for the service to "change perception of self"*

Most of the participants (n=12) would pay between $11-$25 to have this service on the plane. Nine participants responded that they would not pay at all. Three participants would pay between $5-$10, four participants would pay more, between $26-$50 and one participant would pay even more, between $51-$75. A Spearman test revealed that there was no significant correlation between ratings of how much participants liked the concept and the maximum amount they were willing to pay (P=0.29; N-29; p>0.05).

With regards to using this concept at work or home the responses are shown in Figure 9, below.

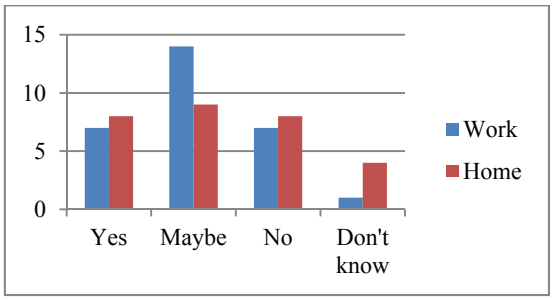

Figure 9: *Comparison of participants' responses to use of concept at work or home*

The participant responses were mixed regarding whether they would use this concept at work or home. Almost half of the participants (n=14) said they "maybe" would use it for work with seven participants responding either "yes" or "no". One participant responded with "don't know". In contrast nine participants said they would "maybe" use it at home with eight participants saying either "yes" or "no" and four participants responding "don't know".

There were nine additional comments. Four were positive with comments such as, *"I liked the rendering of virtual characters";* and *"We can use it in relax time or use it in our work"*. Three comments related to concerns over sickness from the HMD and motion, e.g. *"The combination of 2 virtual motions concern me on how cyber sick a person would be"*. Two comments related to realism, e.g. *"In order to be useful, the sense of immersion and presence should be very high to really forget the "real" environment"*.

3.2. Changing the perception of self and space

Fifty-one participants experienced this demonstration. Seven questions were asked about this concept. The ratings of how much the participants liked the concept are shown in Figure 10 below.

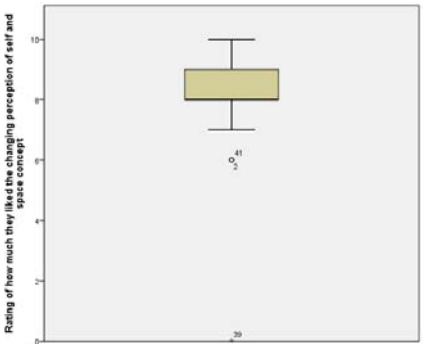

Figure 10: *Boxplot showing the ratings from 0-10 of how much the participants liked the "changing the perception of self and space" concept.*

Generally all the participants liked this concept (median rating of 8.5 (IQR= 1). Almost two-thirds of the participants (n=32) said "yes" they would use this on a plane, with almost a third, (n=15) responding "maybe". Only two participants responded with "no" or "don't know". Similarly, 33 participants said "yes" and 14 participants said "maybe" it would enhance their flight experience with two participants responding "no" and "don't know".

With regards to the maximum the participants were willing to pay for this service on the plane, the results are shown in Figure 11 below.

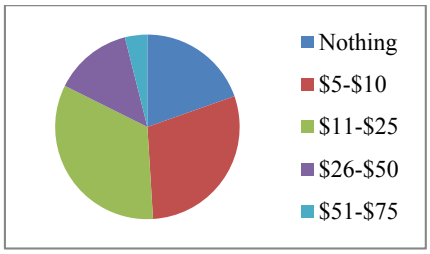

Figure 11: *Maximum amount participants were willing to pay for the service to "change perception of self and space"*

Around a third of the participants would pay either between $11-$25 (n=17) or $5-$10 (n=15) to have this service on the plane. Ten participants would pay nothing at all but seven participants would pay more, between $26-$50 and two participants would pay between $51-$75. A Spearman test revealed that there was no significant correlation between ratings of how much participants liked the concept and the maximum amount they were willing to pay (P=0.24; N=50; p>0.05).

With regards to using this concept at work or home the responses are shown in Figure 12, below.

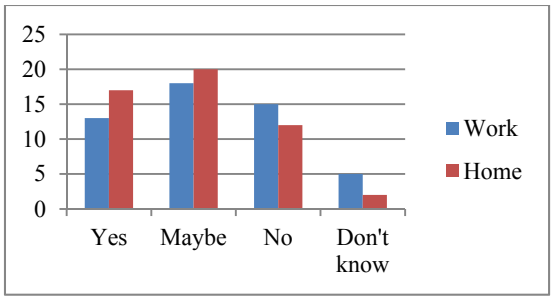

Figure 12: *Comparison of participants' responses to use of concept at work or home*

The responses were mixed. Eighteen participants said they "maybe" would use it for work, with 13 participants responding "yes" and 15 participants responding "no". Five participants responded "don't know". Similarly, 20 participants said they would "maybe" use it at home, with 17 participants saying "yes", 12 participants saying "no" and two participants responded "don't know".

There were 21 additional comments. Three participants said they would like more content in the virtual environment to increase engagement, e.g. *a variety of surroundings, real imagery and live flight data in addition to fantasy environments.* Three participants commented on the "speed" of the environment e.g. *"love it, want to go faster ☺"* and *"it would be nice if the user could control the flight speed, rotation, etc."* Eight comments provided positive feedback, e.g. *"I think the concept is very good and promising especially if you merge it with other sensory data; by tracking body for instance, and with the ability to fly freely"*. Four comments were related to sickness – how it may cause sickness - *"I got cybersick a little bit. I think I'll get more sick if I use this on a plane"*. One participant said they would pay a one time fee while another participant said that they would pay if it did not cause sickness. Another participant suggested that matching the movement may actually reduce motion sickness. One person said that they would prefer to go and walk outside rather than use at home or work, while another said they would prefer to do other things on a plane like reading and working which could be difficult with an HMD,

3.3. The Enhanced Airplane Cabin

Thirty-nine participants experienced this demonstration. Nine questions were asked in total about this concept. The ratings of how much the participants liked the concept are shown in Figure 13 below.

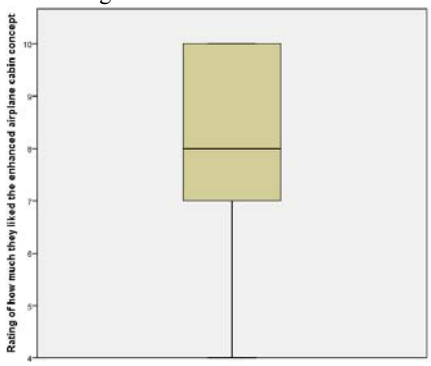

Figure 13: *Boxplot showing the ratings from 0-10 of how much the participants liked the "enhanced cabin" concept.*

Generally all the participants liked this concept with a median rating of 8 (IQR= 3). Over two-thirds of the respondents (n=29) said "yes" they would use this on a plane with almost a third (n=11) responding "maybe". Only 1 participant responded with "no". Similarly, over three-quarters of the participants (n=30) said "yes" and seven participants said "maybe" it would enhance their flight experience. One participant responded "no" and one participant responded "don't know".

With regards to the maximum the participants were willing to pay for this service on the plane, the results are shown in Figure 14 below.

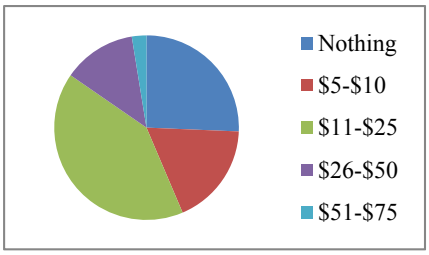

Figure 14: *Maximum amount participants were willing to pay for the service "an enhanced cabin"*

Sixteen participants would pay between $11-$25, while ten participants would pay nothing. Seven participants would pay between $5-$10 while five participants would pay more - between $26-$50 - and 1 participant even more - between $51-$75. A Spearman test revealed that there was a significant positive correlation between ratings of how much participants liked the concept and the maximum amount they were willing to pay (P=0.42; N-39; p<0.05).

With regards to using this concept at work or home the responses are shown in Figure 15, below.

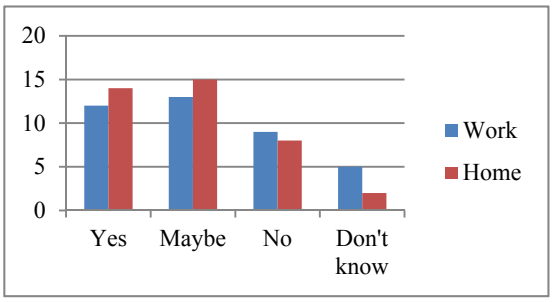

Figure 15: *Comparison of participants' responses to use of concept at work or home*

The responses were mainly positive. Twelve participants said "yes" they would use it for work with 13 participants responding "maybe". Nine participants responded "no" and five participants responded with "don't know". Similarly, 14 participants responded "yes" and 15 participants responded "maybe" they would use it at home. Eight participants responded "no" and two responded "don't know".

When travelling by aeroplane, 33 participants said "no" to sitting in a middle seat in a row of seats, with one participant responding "yes" and qualified this by adding, *"My choices regarding middle seats are made due to my height (1.95m). Being shorter, I would choose the middle seat"*. Two participants responded "sometimes" and three participants responded "don't mind". However, with this technical set up, only 14 participants said, "no" to sitting in the middle seat, 7 responded, "yes", 16 participants responded, "sometimes" and 2 responded "don't mind".

There were nine additional comments. Four participants liked the idea because it was *"cool"* with one saying because *"I can see my work, laptop, food, fellow passenger, etc."* One participant did not understand why you would see just clouds (but they obviously did not see the other possible environments). Another participant said they would use at home depending on the types of environments you could have. Four participants commented on the choice of middle seat saying, *"I like looking out the window. This would probably make a middle seat experience better"; "I would use this setup and choose middle seats but for short flights"*; and "*no middle seat because this tech still won't get rid of advantage exit rows have of ease of ingress, egress and access"*. One participant was unsure if people would use it unless for long haul flights and possible only business class depending on cost.

3.4. Social and Communal Spaces in the Airplane Cabin

Thirty-nine participants watched this demonstration. Eight questions were asked about this concept. The ratings of how much the participants liked the concept is shown in Figure 16 below.

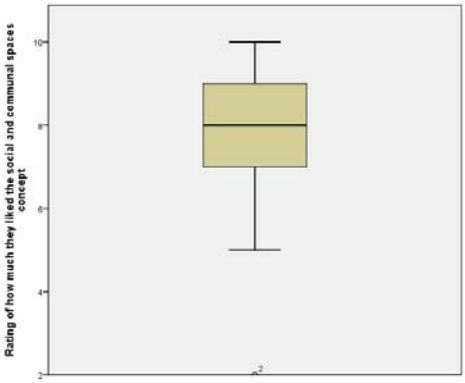

Figure 16: *Boxplot showing the ratings from 0-10 of how much the participants liked the "social and communal spaces in the air cabin cabin" concept.*

Generally all the participants liked this concept with a median rating of 8 (IQR= 2). A third of the participants (n=13), said "yes" they would use this on a plane with over a half (n=21) responding "maybe". Only 3 participants responded with "no" and 2 participants responded "don't know". Similarly, over half (n=21) said "yes" and 14 participants said "maybe" it would enhance their flight experience with one participant responding, "no" and three participants responding "don't know".

With regards to the maximum the participants were willing to pay for this service on the plane, the results are shown in Figure 17 below.

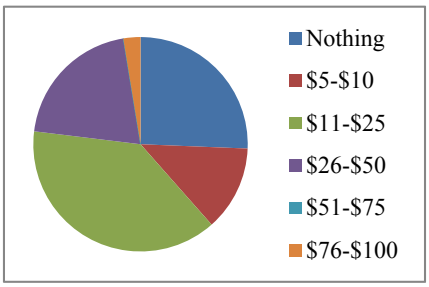

Figure 17: *Maximum amount participants were willing to pay for the service "social and communal spaces"*

About a third of the participants (n=15), would pay between $11-$25 to use this concept on a plane. A quarter (n=10), would pay nothing at all but eight participants would pay between $26-$50. Five participants would pay between $5-$10 and 1 participant would pay between $76 - $100. A Spearman test revealed that there was no significant correlation between ratings of how much

participants liked the concept and the maximum amount they were willing to pay (P=0.24; N=50; p>0.05).

With regards to using this concept at work or home the responses are shown in Figure 18, below.

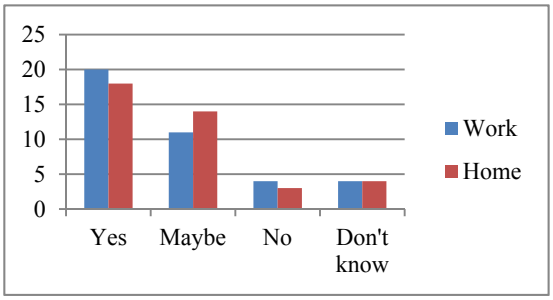

Figure 18: *Comparison of participants' responses to use of concept at work or home*

The responses were highly positive. 20 participants said "yes" they would use it at work, 11 participants responded "maybe" and only four participants responded "no" or "don't know". Similarly, 18 participants responded "yes" they would use it for home and 14 participants responded "maybe". Only three participants responded "no" and four responded "don't know".

The participants were asked to rate a number of features demonstrated by this concept on a rating scale from 0-10 (0 being "not desirable" and 10 being "extremely desirable"). The results are shown in Table 1 below.

Table 1: *Rating responses on a scale of 0-10 (0 being "not desirable" and 10 being "extremely desirable").*

Concept	Median	IQR
Telepresence (virtual steward /friends/colleagues)	7	4
Large multi-user 3D displays on seatbacks for interacting with other passengers	7	3.5
Communal multi-user 3D for interacting with remote colleagues using telepresence	7	2.75
Virtual windows (cabin walls made transparent)	9	2

There were eight additional comments. Two participants provided positive feedback, one saying that they would pay for this on a long haul flight and another suggested the added feature to "*record the view from the same flight so it's available on subsequent flights to replay, rewind and forward*". Two participants commented on the problem with sound of *"lots of passengers conferencing at the same time [this] will end up with noise and leading to passengers disturbing each other."* One participant asked about unwanted sharing by passengers and another had concerns about limited movement, saying that it *"does not promote physical exercise on planes, even though this is critically important to avoid DVT."* Another participant commented, *"For me, a flight is a time to disconnect from the world. But sounds like a good concept for those who want to talk."*

3.5. Inflight tele-operations on Mars

Twenty-six participants viewed this demonstration. Seven questions were asked in total. The ratings of how much the participants liked the concept are shown in Figure 19 below.

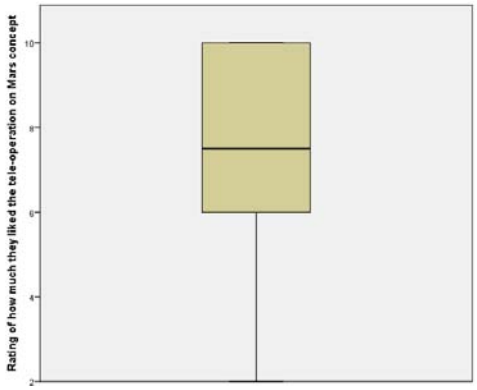

Figure 19: *Boxplot showing the ratings from 0-10 of how much the participants liked the "teleoperation" concept*

Generally all the participants liked this concept with a median rating of 7.5 (IQR= 3.75). About a third of the participants, (n=8) said "yes" they would use this on a plane and 11 participants responded "maybe". Five participants responded with "no" and two participants responded "don't know". Similarly, nearly a quarter (n=6) responded "yes" and a half, (n=13) said "maybe" it would enhance their flight experience, with five participants responding with "no" and 2 participants responding "don't know".

With regards to the maximum the participants were willing to pay for this service on the plane, the results are shown in Figure 20 below.

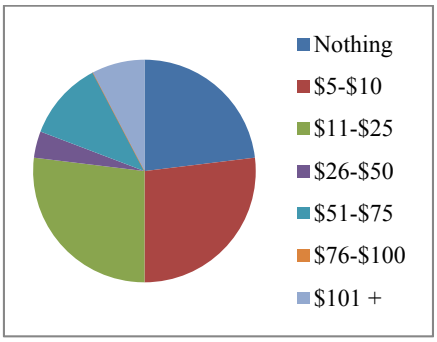

Figure 20: *Maximum amount participants were willing to pay for the service "teleoperation"*

Around a quarter of the participants (n=7) would either pay between $5-$10 or $11-$25 to use this service on a plane, with six participants who would pay nothing. One participant would pay between $26-$50, three participants would pay between $51-$75 and two participants would pay significantly more - $101 and higher. A Spearman test revealed that there was a significant positive correlation between ratings of how much participants liked the concept and the maximum amount they were willing to pay (P=0.55; N=26; p<0.05).

With regards to using this concept at work or home the responses are shown in Figure 21, below.

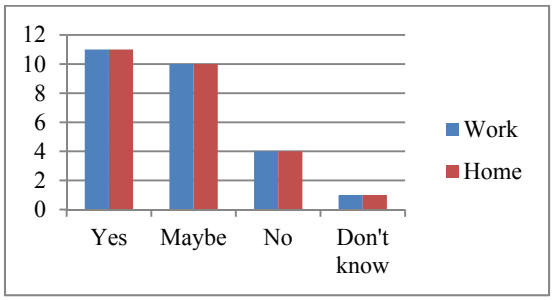

Figure 21: *Comparison of participants' responses to use of concept at work or home*

The responses were highly positive. With 11 participants responding "yes" they would use it at work and home, 10 participants responding "maybe" and only four participants responding "no" and one participant responding "don't know".

There were six additional comments. Two positive comments with one participant saying that they liked the idea of being "*in control of something else*". The four negative comments were mainly about the participants not able to see the added value of the service being on a board a plane, and potential latency issues.

4. Discussion

This was the first public demonstrations of the VR-HYPERSPACE concepts. The conference at IEEEVR2014 was a great opportunity to reach a wide number of VR-enthusiasts, arguably the initial consumers of our applications. While previous studies of the project were aimed at investigating passenger comfort, it was also important from the view point of our industrial partners, TAS-I and Airbus Group, whether passengers would use these applications and their willingness to pay for such services. It was a chance to see if the on-going scientific work in labs could be transferred to the real world and within an aviation context. For this reason, the evaluation was designed as a consumer survey so that we could capture key feedback on opinion, use and costs.

The results showed that initial feedback was highly positive. The demonstrations generated a lot of interest within the conference and the participants generally liked all the concepts and could see the possibilities for using them at work and home. In most cases less than a quarter of the participants would pay nothing for these as a service but encouragingly most of the participants would pay between $11-$25. The feedback shows great promise towards the use of VR for in-flight applications.

Finally, the demonstrations also provided the opportunity for researchers at MPG to test illusions on a long haul flight, as shown in Figure 22 below.

Figure 22: *MPG Researcher testing space illusions with an HMD and smartphone on a long haul flight (MPG, Germany)*

In-flight applications of VR are not such a distant future!

Acknowledgements

This research has received funding from the EC FP7 project VR-HYPERSPACE (AAT-2011-RTD-1-285681 www.vr-hyperspace.eu). In particular, the authors acknowledge the tremendous contribution of all the partners and researchers on VR-HYPERSPACE.

References

[BKKF13] Beck, S., Kunert, A., Kulik, A., and Fröhlich, B. (2013) Airborne Avatars - Inflight Immersive Telepresence. *5th Joint Virtual Reality Conference (JVRC2013), Campus Paris Saclay, France, Decmber 11-13th, 2013*

[DPL*14] D'Cruz, M., Patel, H., Lewis, L., Cobb, S., Bues, M., Stefani, O., Grobler, T., Helin, K., Viitaniemi, J., Aromaa, S., Froelich, B., Beck, S., Kunert, A., Kulik, A., Karaseitanidis, I., Psonis, P., Frangakis, N., Slater, M., Bergstrom, I., Kokkinara, E., Mohler, B., Leyrer, M., Soyka, F., Gaia, E., Tedone, D., Olbert, M., Cappitelli, M. (2014) Research Demonstration: VR-HYPERSPACE, The Innovative Use of Virtual Reality to Increase Comfort by Changing the Perception of Self and Space. *IEEEVR2014, Minnesota, Minneapolis, March 29 - April 2, 2014*

[KBS13] Kilteni, K., Bergstrom, I., & Slater, M. (2013). Drumming in immersive virtual reality: the body shapes the way we play. *IEEE Transactions on Visualization and Computer Graphics*, *19*(4), 597–605.

[Moh13] Mohler, B. (2013) Perception of indoor and outdoor virtual spaces. *5th Joint Virtual Reality Conference (JVRC2013), Campus Paris Saclay, France, December 11-13th, 2013*

.

[RBW05] Regenbrecht, H., Baratoff, G. and Wilke, W. (2005) Augmented reality projects in the automotive and aerospace industries. *IEEE Computer Graphics and Applications, Vol: 25, Issue 6, pp. 48-56*

[SPS11] Stone, RJ., Panfilov, PB. and Shukshunov,VE. (2011) Evolution of Aerospace Simulation: From Immersive Virtual Reality to Serious Games. *Proceedings of 5th International Conference on Recent Advances in Space Technologies (RAST) 2011; pp. 655-662*