Virtual Reality – Quo Vadis?
How to Address the Complete Audience of an Emerging Technology

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Abstract

With the introduction of the first affordable high-quality head mounted displays such as the HTC Vive and Oculus Rift in 2016 the "old technology" (Sutherland, 1965) of virtual reality (VR) has experienced quite a boost: it seems foreseeable that the once "geek and nerd" (Mizer, 2013) technology will attract a growing consumer audience and is going to find its place within the universe of entertainment besides its already frequent use in engineering. However, when consumer VR applications are presented the two focused key audiences are on the one hand the cliché young male (intended use: gaming) (Hern, 2014) on the other hand high end professionals (intended use: engineering, etc.). If this trend continues not only a majority of potential users will be excluded but rather the applications and their content cannot unfold the technology's full potential at all.

1. Introduction

Head mounted displays (HMD) and virtual reality (VR) are absolutely no new phenomena. Already in the second half of the 20th century, there were first prototypes. As early as 1969 Ivan Sutherland developed a "virtual reality head mounted display system" (Burton, 2017). This system was so heavy, it had to be mounted on the ceiling. There were even some older technologies (Sherman, 2002) but the systems were not ready for the consumer market. A big step in the VR-development was the affordable and relative light weighted system "Oculus Rift DK I" (Luckey, 2012) that paved the way for further progression towards a mass market like the "HTC Vive" (HTC 2017).

With a growing number of technologies ready for the consumer market chances are good that sales are also increasing from 2.5 in 2016 to 25.5 million US Dollar in 2021 (Statista, 2017). Forecasts also predict that hardware will only represent a major portion of sales until the market's zenith is reached. After that, the essential part will be the software and actual content (Bitkom, 2016). Thus, VR needs a new approach of content since it is foreseeable that a plain game orientated focus (Mizer, 2013) will only address a fraction of the potential target audience.

The investigation "Gender Differences and VR: A Non-User Survey of What Women Want" from 1994 by Carrie Heeter showed that women were less likely to use VR: "[...] Women also do not play today's video games. Although it is clear that women are not attracted to the current battle-oriented VR experiences, what women DO want from VR has received little attention." Heeter postulated that women are less likely to play games in general–therefore, VR was considered a male dominated pleasure with focus on gaming–at least in 1994. A newer investigation however analyzed the distribution of computer and video gamers in the United States from 2006 to 2017, by gender and showed a rising number of female gamers in the past years: Almost half of the gamers are female today (Statista, 2017b). How can this trend to digital content be utilized to open VR to a wider audience? And furthermore: Is gaming, the only consumer experience that can be established as the most essential VR content?

2. Study and Hypothesis

We re-evaluated Heeter's study published in 1994 that questioned content preferences from users who have not experienced VR and probably had only a vague idea what it might be (since the study was conducted in 1993 it is not surprising that this technology had not yet found a widespread distribution).

We conducted a similar study that questioned 168 test persons between the age of 17 to 50 (mean age: 27 years) of which 89 were female and 76 were male. In contrast to the cited study by Heeter the majority (more than 66%) of our test population had already experienced applications in VR at least once–whereby we noticed a significant gender difference–maybe due to the mentioned cliché: over 48% of our female test population has not tried VR compared to 21% of males. What needs to be done in order to delight women to give VR a chance in their media consumption habits? Are Heeter's results after almost 25 years–what is an aeon in computer technology–and with up-to-date media perception habits still correct?

2.1. Method

The survey was conducted via an online questionnaire that was online from June 25th to 28th 2017. The participation was voluntary, the used language for the questionnaire was German. We did not track any other data other than the direct questions. The participants' IP-address was anonymized and not saved.

2.2. Results: Gender & VR

Participants were given the same seven hypothetical scenarios as defined by Heeter for the sake of comparison. Each hypothetical scenario could be rated from 1 (= not interested) to 7 (= highly interested). As shown in Table 1 the interest figures look quite balanced–yet there are still some typical male clichés (i.e. the interest in Games and Combat), but there are as well scenarios where females feature, also in 1994, significant higher interest rates than men (i.e. Fitness and Travel).

Gender	Virtual Fitness	Virtual Presence	Virtual Sex	Virtual Travel	Virtual Games	Virtual Learning	Virtual Combat
female 2017	4.75	4.33	3.57	5.41	4.98	4.90	3.03
male 2017	3.67	4.58	4.38	5.18	5.78	4.35	4.78
female 1994	5.6	5.3	4.4	6.3	4.9	5.4	3.0
male 1994	4.9	5.7	5.7	6.1	6.5	5.9	5.6

Table 1: Mean values of interest rates (1 = not interested; 7 = highly interested) of different activities in relation to gender in VR. These values were calculated using the mean of each individual gender's average as normalization. The rows "female 1994" and "male 1994" cite the figures from Heeter 1994.

With this finding we can state, that although the technology needs to advance the salient point of gender differences in VR is the differing demand of content and application scenarios that women ask for. This effect is similar to conventional media: i.e. the significant gender differences in TV content preferences (IfD Allensbach, 2016) that show that males and females have different media consumption habits in general.

It is interesting to note that the average interest in VR in 1994 was in average 5.38 (male: 5.77; female 4.99) while in 2017 it was 4.55 (male: 5.67; female 4.42). If this effect, however, is caused by a cross-

cultural self-report measure difference[1] or by an actual lower interest in VR cannot be determined by the given results.

Gender	VR Experience	#	Virtual Fitness	Virtual Presence	Virtual Sex	Virtual Travel	Virtual Games	Virtual Learning	Virtual Combat
female	with	43	4.93	4.54	3.86	5.46	5.20	4.96	3.37
female	without	46	4.57	4.12	3.27	5.37	4.75	4.84	2.69
male	with	63	3.73	4.57	4.37	5.32	5.87	4.37	4.84
male	without	13	3.61	4.58	4.39	5.03	5.68	4.33	4.72

Table 2: Mean values of interest values in different activities in VR (1 = not interested; 7 = highly interested)

In comparison to Heeter's results there seems to be a change in gender differences: The relative higher interest for males in comparison to females[2] in 1994 is 16% while in 2017 is only 6%. As shown in Table 1 females reached in our study higher mean values in the categories "Virtual Learning", "Virtual Fitness" and "Virtual Travel". Only in the mentioned category "Virtual Fight" and in "Virtual Games" as well as "Virtual Sex" men are still more interested than women. Almost identical results were noted at "Virtual Presence". This gender-gap gets even more close when the individual experience with VR of the test subjects is put into consideration: Table 2 subdivides both gender groups into parts with and without experience. As we can see: Having tried VR at least once increases the interest in each scenario and brings both genders closer together (male: 4.72; female: 4.62; relative difference: 2%).

Regarding the statistical relevance of the impact of gender or VR experience respectively on the interest figures of the particular scenario, we conducted an analysis of variance (ANOVA). As Table 3 shows we can state that with a few exceptions gender as well as VR experience can have a significant influence[3] on the different scenario's ratings.

Attribute	Virtual Fitness	Virtual Presence	Virtual Sex	Virtual Travel	Virtual Games	Virtual Learning	Virtual Combat
VR Experience	0.39	0.13	<0.001	0.07	<0.001	0.96	<0.001
Gender	<0.001	0.065	<0.001	0.25	<0.001	0.08	<0.001

Table 3: p values of an ANOVA on the impact of the participant's attribute on the preference of different scenarios.

2.3. Paradigm shift

Looking beyond the cliché confirmations of gender stereotypes, it could be stated that one of the most interesting phenomena is not gender-specific at all: While the study by Heeter was only able to question the interest in VR in general without the ability to differentiate between experience levels we can now present these results. In Table 2 and 3 we can easily observe that interest in every category is not only correlated to the state of the test person's gender but rather also on his/her individual VR experience: persons with VR experiences are more likely to be interested in all kind of investigated

[1] These cultural determined differences can have a significant impact on the findings (Harzing, 2006): I.e. Dolnicar/Grün (2007) found out that over 6% of cross-test-group differences can be attributed to cultural differences in survey response patterns.

[2] In the 90ties computer and media technology was still considered as a male dominated culture (Bjorkman et al. 1998). This gender gap was closed at the latest with the pervasion of smartphones in popular media usage habits and even reversed in 2015 when females used their smartphone longer than their male counterparts on average (Andone et al., 2016).

[3] Small p-values (< 0.05) are indicators for statistical significance (Rice, 1989).

activities, regardless of gender. If this effect, however, is caused by VR experience, a-priori VR interest or can be explained with a general higher interest in new technologies stays unclear[4].

With this results in mind, chances seem good that the remaining 48% (female) and 21% (male) unexperienced-VR-users would have a higher interest in VR if they would try at least once.

Used VR	Virtual Fitness	Virtual Presence	Virtual Sex	Virtual Travel	Virtual Games	Virtual Learning	Virtual Combat
never	3.74	4.23	3.42	4.57	4.61	4.54	3.16
once	4.24	4.75	4.34	5.16	5.23	4.62	3.71
more often	4.40	4.47	4.01	5.53	5.73	4.71	4.32

Table 4: Mean values of interest rates (1 = not interested; 7 = highly interested) of different activities in relation to VR experience, regardless of gender. These values were calculated using the mean of each individual gender's average as normalization.

The values suggest that if a person has tried VR at least once the rates of interest grow significantly in every given scenario (excluding "Learning"). With this new paradigm in mind the question arises what has to be done in order to address non-VR users to get in touch with this technology. What kind of content and environment do they prefer and what kind of interactions within VR should be possible to lower the threshold for this target audience?

2.4. Desired content approach of different test groups

In this section the participants were asked what kind of visual content they would prefer in general. One of the most significant findings here was the declining crave for visual realistic environments with inclining VR experience. Also, the desire of world-like physical paradigms (e.g. gravitational force) is declining when users can draw on prior VR experience. When asked about the desired look of their own avatar inside the virtual environment non-VR users preferred a rather realistic approach (mean: 3.71 on a scale from 1 (= realistic) to 7 (=fantasy)) whereas frequent VR-users went after a fantasy-like design (4.54). In terms of the visual approach of the given environment non-users also preferred a more realistic (mean: 4.32 on a scale from 1 (=fantasy) to 7 (=realistic)) design compared to test persons with VR experience (3.70). When questioned on the importance of realistic behavior of virtual environments (e.g. gravity) it can be stated that the desire for nature-like paradigms also decreases with VR experience: Non-users answered with a mean of 3.82 (on a scale from 1 (=very important) to 7 (=not important at all) while test persons with VR experience answered with a mean of 4.54.

In summary the non-VR users tried to picture the material world within the virtual environment. In order to open up the potential user group of inexperienced persons we can state that realistic environments, paired with realistic-looking avatars and realistic physics are elements that non-VR-users expect. Once they are familiar with this technology their tolerance to different approaches of virtual environments rises. What also should be mentioned is the fact that the demand of high quality images is a little lower (mean: 5.23 on a scale from 1 (= unimportant) to 7 (= highly important) than the average of experienced users (mean: 5.79)).

[4] The question after their tech-savviness was answered by non-VR-Users with a mean of 4.17 (1 = not tech-savvy at all; 7 = very tech-savvy) in comparison to a mean of 5.66 for frequent VR-users.

2.5. Desired activities of different test groups

The test population was asked what kind of activities they preferred to have an impact on their experience in VR. They were given 16 activities that could be ranked in their subjective importance from 1 (= very little) to 7 (= very much).

When looking at Table 5 it can be stated that the most important activity that should influence the virtual experience is *Exploring* that achieved in every user group the highest values and its overall mean of 6.02 outnumbers every other activity's measured value. With inclining experience in VR *Exploring* gains in relevance and can be considered as *very important* in every user group.

Activity	Often used VR *n=71*	Once used VR *n=39*	Never used VR *n=57*	Mean	Male, normalized Mean	Female, normalized Mean
Visual Quality	5.58	5.77	5.23	5.53	5.74	5.53
Being a Scientist	4.86	4.44	4.39	4.56	4.87	4.50
Exploring	6.24	6.08	5.75	6.02	6.03	5.98
Leadership	3.72	4.10	3.95	3.92	4.28	3.89
Dexterity	4.85	5.15	5.09	5.03	4.92	5.27
Luck	3.18	3.59	3.96	3.58	3.72	3.68
Fighting	3.24	3.31	3.02	3.19	3.93	2.86
Communication	4.92	5.15	4.70	4.92	4.93	5.12
Creativity	5.52	5.69	5.47	5.56	5.53	5.77
Physical Fitness	3.83	3.67	4.32	3.94	4.02	4.26
Risk-Taking	4.48	4.56	4.65	4.56	4.84	4.51
Solving a Mystery	5.03	4.92	4.67	4.87	4.87	5.10
Learning while Playing	5.41	5.54	5.02	5.32	5.72	5.25
Teamwork	4.86	4.85	4.77	4.83	4.87	4.97
Prior Knowledge	3.24	3.23	3.58	3.35	3.73	3.31
Competition	3.51	3.97	3.44	3.64	3.98	3.52

Table 5: Mean values of different given activities in virtual environments across user groups. (1=not important; 7=very important)

Regarding the question which activity is least desired in VR the measured values differ slightly between the user groups: Experienced users who have often used VR disliked the activity *Luck* whereas probands who never tested VR before showed the largest disapproval at the activity *Fighting*. The overall least desired activities were *Fighting* (mean: 3.19), *Prior Knowledge* (mean: 3.35), and *Luck* (mean: 3.58)–although the category *Prior Knowledge* is among the activities that was ranked higher by unexperienced users in relation to experienced user groups (other activities that ranked higher among probands that never used VR: *Physical Fitness*, *Luck*, and *Risk Taking*).

Since our study featured vast differences in VR experience between male and female test persons we normalized the results by calculating the mean of each experience level among each gender separately and used this values as basis for the final mean calculation.

The largest difference between each gender's preference could be measured at the activity *Fighting* with a distance of 1.06, followed by *Learning while Playing* (distance: 0.47), and *Competition* (distance: 0.46). The smallest distances that could be measured across the genders are also among activities that produced the most extreme results in general: Males as well as females correspond with their favorite activity *Exploring* (overall mean: 6.02, distance between male and female: 0.05) as well as their denial of *Luck* (overall mean: 3.58, distance: 0.04).

2.6. Desired genres of different user groups

In her study Heeter (1994) also included the question which genres–in terms of movie/TV genres–the test persons preferred. Although this question seems a little bit outdated on first sight because VR can offer a lot more interactivity than sheer movies by now we however decided to include this question as well in our recent study because it offers known evaluation benchmarks that even test persons with zero VR experience (still roughly ⅓ of our study's test population) can easily relate.

The test persons were given 16 different genres that they could rank from 10 (= would enjoy very much) to 0 (= would not enjoy at all).

TV genre	Often used VR n=71	Once used VR n=39	Never used VR n=57	Mean	Male, normalized Mean	Female, normalized Mean
Adventure	8.21	7.49	7.04	7.58	7.66	7.53
Comedy	4.03	4.92	3.79	4.25	3.42	4.74
Documentary	7.52	7.41	7.26	7.40	7.89	7.25
Drama	4.41	4.85	4.44	4.57	4.71	4.79
Erotic	4.56	5.49	3.26	4.44	5.81	3.70
Horror	4.90	3.69	2.56	3.72	3.81	3.43
International Culture	6.20	5.33	5.25	5.59	5.48	5.97
Detective/Cop	6.04	5.74	5.86	5.88	5.83	6.11
Live Events	6.28	6.95	6.53	6.59	6.37	7.00
MTV	5.82	6.79	6.84	6.48	6.58	6.66
Science Fiction	7.10	6.44	4.72	6.09	6.79	5.33
Soap Opera	1.59	2.10	1.98	1.89	1.70	2.37
Splatter	3.59	3.08	1.93	2.87	3.53	2.44
Sports	4.44	5.36	5.02	4.94	5.11	5.24
Talk	1.63	2.21	1.60	1.81	1.51	2.05
Science & Education	7.28	7.08	6.86	7.07	7.61	7.01

Table 6: Mean values of different movie/TV genres across user groups. The participants could rank the given experiences from 10 (would enjoy very much) to 0 (would not enjoy at all).

As seen in Table 6 the most interesting genres are *Adventure*, *Documentary* and *Science & Education*. This correlates also with the learnings about activity preferences in paragraph 2.5 where *Exploring* being the most favorite activity. The least desired genres were *Talk* (mean: 1.81) and *Soap Opera* (mean: 1.89) although a small gender gap emerges with a distance of 0.54 (*Talk*) respectively 0.66 (*Soap Opera*). The largest distances between measured preferences could be observed at the genres *Science Fiction* (distance between normalized male and female mean: 1.46), *Erotic* (distance: 2.11), and *Comedy* (distance: 1.32).

2.7. Desired sensations of different user groups

The participants were asked about their interest in four different sensations that they could rank on a scale from 1 (= very little interested) to 7 (= very much interested). The sensations could be classified in *Physical Sensations*, *Visual and Auditory Sensations*, *Intellectual Stimulation*, and *Emotional Experiences*. Following the style of Heeter's (1994) study each sensation was questioned by providing a small example in order to facilitate the inner visualization. *Physical Sensations* were introduced by the example "Imagine being able to fly like a bird or jump down a cliff without worrying about injury." *Visual and Auditory Sensations* were questioned with the example of "breathtaking landscapes, detailed facial expressions of an alien", *Intellectual Stimulation* with

"content and experiences that make you think or learn", and *Emotional Experiences* with "experiences that evoke emotional responses".

Sensations	Often used VR	Once used VR	Never used VR	Mean	Male, normalized Mean	Female, normalized Mean
Physical sensations	5.96	5.69	5.89	5.87	5.95	5.80
Visual and auditory sensations	5.80	5.59	5.12	5.52	5.39	5.57
Intellectual stimulation	5.27	5.28	5.00	5.18	5.45	5.13
Emotional experiences	4.86	4.95	4.46	4.74	4.98	4.69

Table 7: Mean values of different sensations across different user groups. The interest in each sensation could be ranked from 1 (= very little interested) to 7 (= very much interested)

As Table 7 shows: There is a visible difference between interest values of frequent VR users and non-VR users–however an ANOVA reveals that these figures differ in their statistical significance: The p-values vary from 0.8 (*Physical sensations*), 0.3 (*Intellectual Stimulation*), 0.2 (*Emotional Experiences*) to 0.02 (*Visual and Auditory Sensations*)–therefore only *Visual and Auditory Sensations* feature significant differences between users and non-users. All other sensations show comparable interest values, whereby *Physical Sensations* are desired most, and *Emotional Experiences* are desired least within all user groups.

2.8. Motion Sickness: Prevalence and Causes

Divergent from Heeter's study we also asked our participants if they ever experienced physical discomfort while using a VR application. If that was the case, they could select from five given answers or had the opportunity to add a free text as well. Since our study featured 33% test persons that had never tested VR we only put participants into consideration that used VR at least once for the following paragraph.

The majority (about 55%, n = 60) of the study's participants with VR experience already went through a form of physical discomfort when using a HMD (Head Mounted Display). Of these 60 probands 56% were male and 44% were female. When asked what effect or feature of VR actually caused the experienced discomfort, 59.8% of this test group answered that there was too much parallel information they had to handle and criticized the excessive speed of the provided content making it unable to process adequately. 53.7% found fault with improper mapping between the displayed image and the underlying technics, 46.3% criticized technical issues (i.e. distortion, insufficient lens quality, bad wear comfort), whereas only 17.1% deprecated insufficient graphics (i.e. bad textures or wrong shadow rendering). 19.5% answered that they are sensitive to multimedia applications in general and their discomfort is not exclusively related to HMDs.

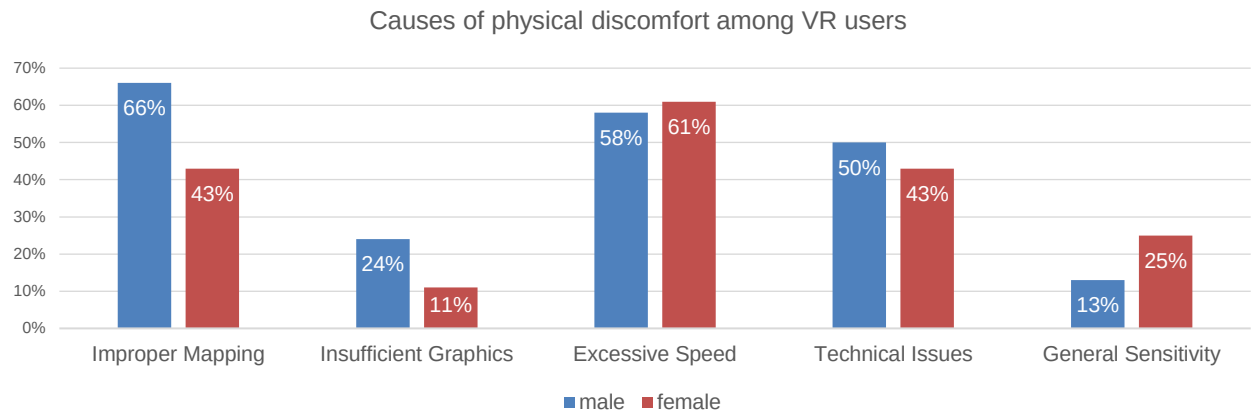

Figure 1: Causes of physical discomfort (multiple choice question) across the genders.

As Figure 1 indicates: There are some subtle gender differences in the cause of the individual discomfort: On the one hand males seem to be more sensitive to improper mapping and insufficient graphics that females, who face on the other hand more problems with general sensitivity in VR.

In the free text area, the participants could point out additional factors, if needed. 19 probands gave additional information here, such as the lack of motion liberty, the absence of fixed points in the virtual world, the physical discomfort when using glasses in combination with a HMD, too strong motion blur effects and problems with first person perspective in general–regardless of the used output device.

Since this study's focus is on content we tried to find relationships between content preferences and prior experiences of discomfort related to VR. By using an ANOVA, we found out that there is a correlation between the desire for the *"virtual world feels and behaves like the real world"* is higher, when the user has experienced in-use-discomfort before ($p = 0.03$). Also the activity *Physical Fitness* (see paragraph 2.5) is ranked significantly higher ($p = 0.05$), when the test person had problems with discomfort before. A comparable relationship was found with the activity *Competition*, that is ranked lower ($p = 0.08$) by participants with VR-related uneasiness.

3. Conclusions and Outlook

VR is a rapidly growing market (Statista 2017). When this technology wants to continue its triumph, it must not exclude large potential user groups. On the one hand our re-evaluation paired with the new introduced parameter of VR experience has shown the different needs of women for virtual environments, on the other hand it proposes a strategy how to address an audience that has not yet experienced VR at all. Regarding this finding we believe a rethinking of gender stereotypes in VR is necessary. Our results also show that the VR market is far from being covered, as the forecasts and the unfulfilled wishes of many users show there is a great potential for this technology in the future. It is meanwhile possible to use VR without spending a lot of money, but this achieves nothing if the right contents are lacking.

As already mentioned, the future VR market will no longer consist of offering hardware, but from suitable applications. Additionally, one should be aware that potential technical problems are not on the long-term, since technologies such as VR are constantly improving. Thus target-group-oriented VR applications are the new challenge in this area. These groups are not just women and men, target groups should be also separated by user's interests. VR consumer technology today primary stands

for "gaming". As long as this is the case, users with other interest may be less interested in using or buying a VR-system in general.

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