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Accelerating Western Balkans University Modernization by Incorporating Virtual Technologies

VTech@WBUni

WP2 - Deliverable 2.6.3

Evaluation of user experience and VR sickness of the developed content

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02	27/10/2022	First revision	Klemen Pečnik, Žana Juvan, Matevž Pogačnik	UL

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1. Introduction

The scope of the Work package 2.6 are usability aspects of VR solutions and lectures, which have been developed in the scope of this project. The goal of the WP is to provide awareness about importance of good user experience, the basics of approach to good user experience, and its evaluation.

The focus of this document is the evaluation of user experience for educational VR solutions, developed by partner Universities. The VR solutions were evaluated according to the guidelines and methodology provided by the University of Ljubljana team. The evaluation included 18 different solutions developed by 5 project partners.

The solutions were evaluated using a predefined methodology, which included the use of standardized user experience questionnaires and some additional relevant user experience questions.

One should also note that there are differences between evaluated VR solutions' specifics due to different usage scenarios, target devices etc.

1.1 Evaluated solutions and methodology

In the scope of the project 18 different VR solutions were evaluated, developed by 5 partner institutions for use in the scope of 18 different courses - 7 of these are intended for Master level courses and 11 for Bachelor level courses. They cover several topics ranging from simulations of electromagnetic fields, COVID detection, architectural design, interactive storytelling, sorting and scheduling algorithms, etc.

1.1.1 Evaluation methodology

The evaluation methodology was based on two standard user experience and usability questionnaires: User experience questionnaire (UEQ) and Simulation Sickness questionnaire (SSQ), complemented by the third questionnaire, that was prepared for the purpose of this project. The additional questionnaire provided us with the demographic data of the participants, information on the use of digital devices and previous experience with VR technology with some additional open questions. The main purpose of the UEQ questionnaire is to evaluate hedonistic and pragmatic aspects of user experience for each of the developed solutions, while the SSQ questionnaire serves as methodology for evaluation of unwanted side effects, which occur during usage of VR solutions, such as sickness, nausea, disorientation, and other VR sickness related effects.

In the following sections the results of evaluations are presented, organized by the order of participating high educational institutions.

2 EPOKA University

In the scope of the project the EPOKA University development team produced 3 VR solutions, each intended for its own course. The following courses' VR application were evaluated:

1. Data structures course with the "Dynamic lists and sorting algorithms" application
2. Circuit theory course with the "Logic gates" application
3. Digital image processing course with the "Image filtering" application

The evaluation results for each course and application are presented in the remainder of this section.

2.1 Course: Data Structures

For the Data structures course the "Dynamic lists and sorting algorithms" application was developed and evaluated. There were 21 participating evaluators, whose demographic profile, digital literacy, UEQ and SSQ results are presented below.

2.1.1 Information about participants

The demographic structure of the participating evaluators is presented in Figures 1 and Figure 2. Most of the participants (95%) were from the age group 18 – 23 years old, while the remaining 5% were participants aged 24 – 29. Women represented 57% of the participants and men 43%.

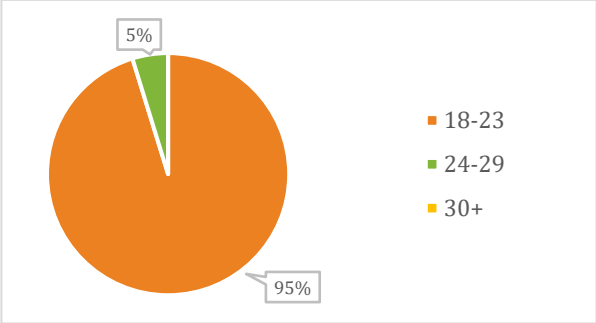

Figure 1: Participants' age distribution

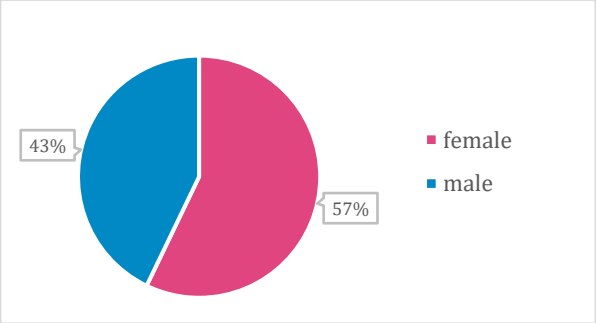

Figure 2: Participants' gender distribution

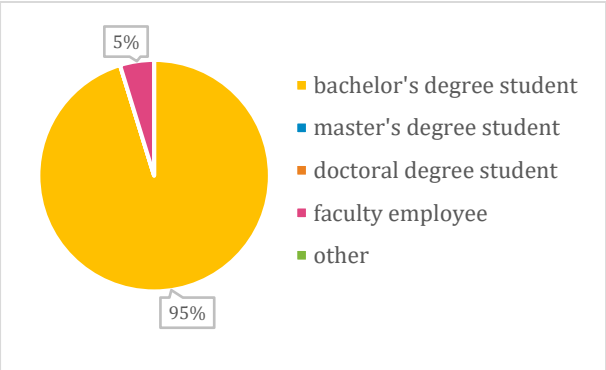

Figure 3: Participants' education and employment

Similarly homogenous was their education and employment. As seen in Figure 3 most participants (95%) were students at a Bachelor's degree level of education and the remaining 5% are faculty employees.

Participants' experience with digital devices is presented in Figures 4 and 5.

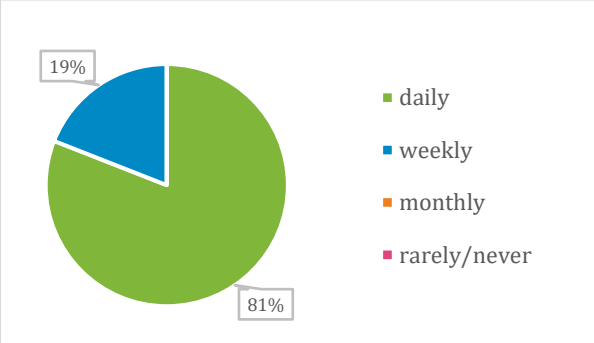

Figure 4: Participant's computer use

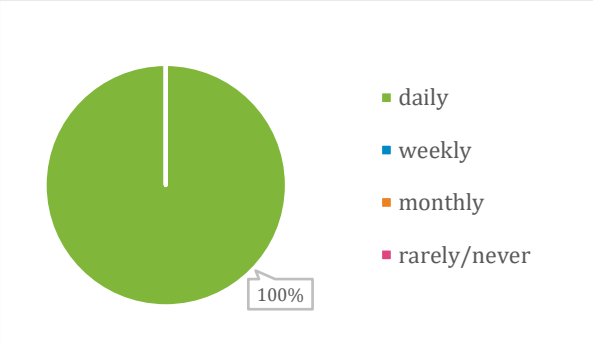

Figure 5: Participants' smart phone use

All participants use their mobile devices daily, with 81% of them also reporting a daily use of the personal computer – the other 19% use it on a weekly basis, as seen in Figures 4 andFigure 5

Usage of VR devices shown in Figure 6 is expectedly not very frequent as 86% of the participants have rarely or never used a VR device before the evaluation. Monthly users of VR devices represent 5% of the participants and 9% represent weekly users of these devices. The majority of previous uses use smartphones for gaming and watching VR videos on YouTube or Netflix.

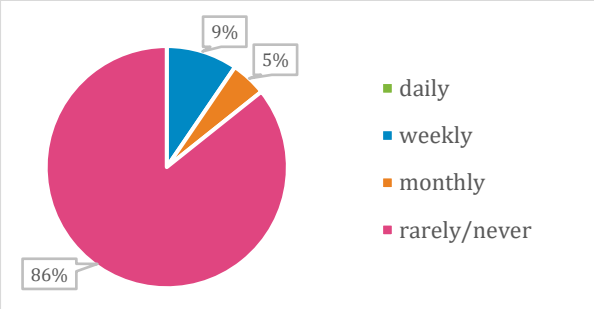

Figure 6: Participants' VR devices use (frequency)

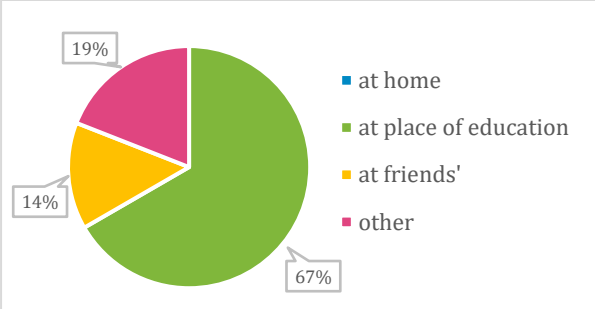

Figure 7: Participants' VR devices use (location)

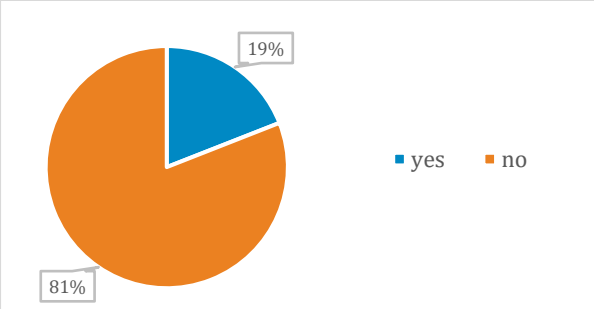

Figure 8: Previous VR sickness experience

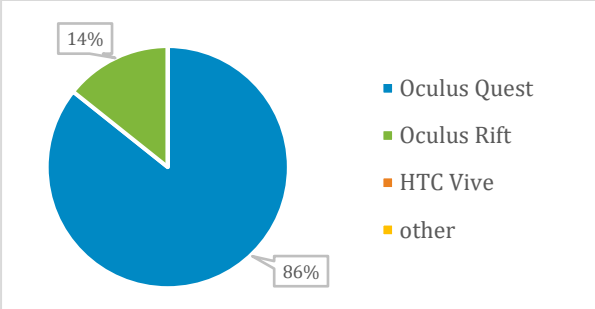

Figure 9: Share of used VR headsets during the experiment

The most frequent location of VR devices' use, shown in Figure 7, is the educational institution (67%), followed by other location (9%) and use at friends' place (5%). Figure 8 shows that 81% have never experienced VR sickness, which very much corresponds with the percentage of users who have never or rarely used such a solution, as seen in Figure 6. Finally, the major share of VR devices used during the evaluation goes to Oculus Quest (86%), with Oculus Rift representing the other 14%, shown in Figure 9.

2.1.2 User experience questionnaire results

The UEQ results, presented in Figure 10, show that the Dynamic lists and sorting algorithms application was well accepted by the participating users. The results across all six scales are more than satisfactory as the hedonistic scales (Stimulation and Novelty) reached "excellent" results, while the pragmatic scales (Attractiveness, Perspicuity, Efficiency and Dependability) reached at least "above average" results, when compared to the database of other evaluated solutions seen in Figure 11. The confidence intervals are satisfactory as well. We can conclude that this solution is good in its design as well as in its implementation.

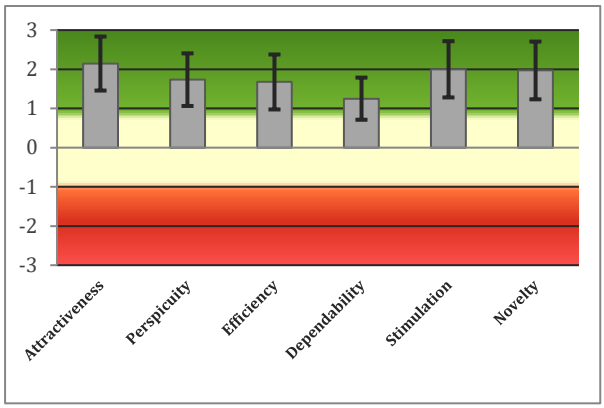

Figure 10: UEQ results for individual scales (Dynamic lists and sorting algorithms)

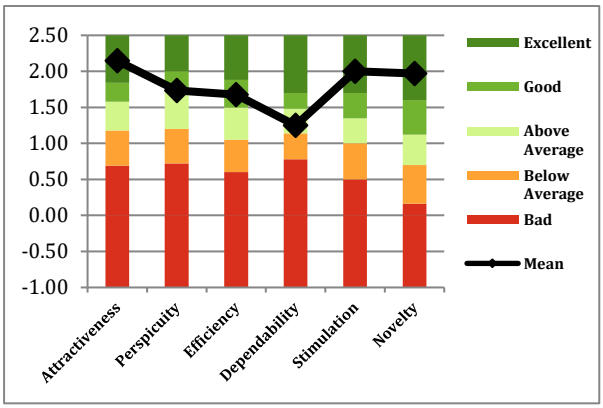

Figure 11: A benchmark comparison of UEQ results (Dynamic lists and sorting algorithms)

2.1.3 Simulator sickness questionnaire score

The SSQ evaluation has given some interesting results as the average values seem to be rather high, causing noticeable discomfort while using the VR application. This is especially true for oculomotor discomfort and feeling of disorientation, while nausea does not seem to have caused an impact. Similar conclusions can be reached from the free questions, where some participants have complained about eye strain and disorientation in space and time. A timed usage with sufficient breaks in-between sessions could help solve these problems. Results are represented in Table 1 and Figure 12.

SSQ Scales (Mean and Variance)		
Scale	**Average**	**SD**
SSQ-N	14.537	18.748
SSQ-O	30.681	33.255
SSQ-D	36.457	54.710
SSQ-T	30.632	36.808

Table 1: SSQ results and variance for the Dynamic lists and sorting algorithms application

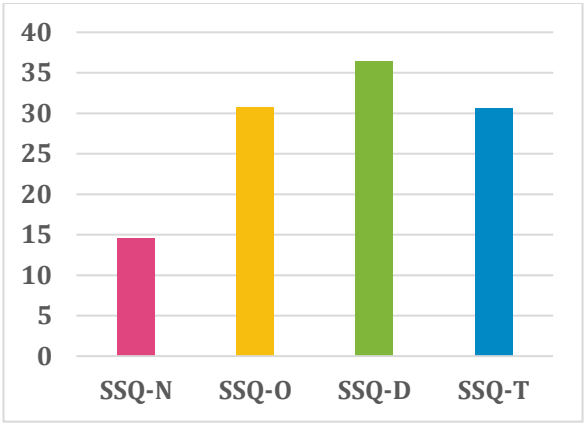

Figure 12: SSQ results for the "Dynamic lists and sorting algorithms" application

2.1.4 General comments and free evaluation feedback

General feedback from the evaluating participants was very positive and encouraging. Most of them were fascinated by the solution, which is to be expected for novel users of VR solutions. They found the idea of VR simulation and presentation of mathematical problems very good and a very useful teaching approach as it is more engaging and immersive for the user. Such applications would help users focus more on the presented topic.

Some suggestions for improvement included change of point of view, which seemed to be too low in some cases, with some remarks regarding the stability and crashing of the used VR headsets. As already mentioned, some participants experienced some eye strain and disorientation and 20 - 30 min usage with breaks in-between was suggested.

In general, the "Dynamic lists and sorting algorithms" application was well accepted and provides good user experience.

2.2 Course: Circuit Theory

There were 15 participants that helped in the evaluations for the Circuit Theory course where they were developing "Logic Gates" application. In the following chapter we will present demographic profile, digital literacy, UEQ and SSQ results.

2.2.1 Information about participants

The first two figures represent the age and gender distribution of the participants. In Figure 13 we see the majority of our participants were aged between 18 and 23 and only 7% were older but still under the age of 29. Women represented 33 % of the participants and there were 67% of male participants, show in Figure 14.

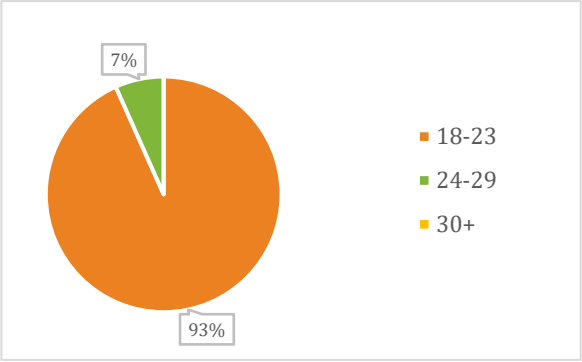

Figure 13: Participants' age distribution

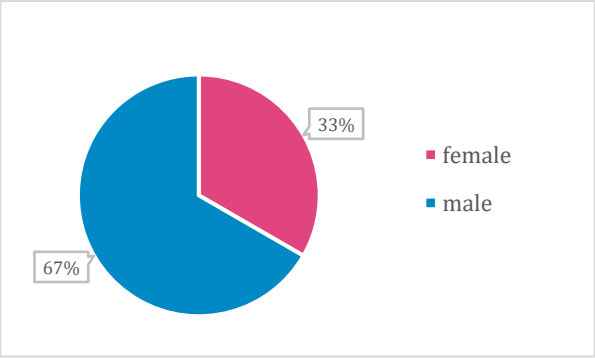

Figure 14: Participants' gender distribution

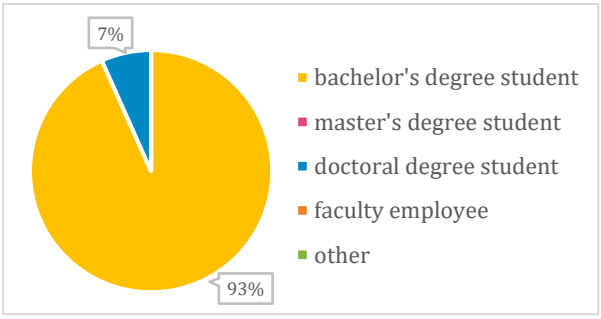

Figure 15: Participants' education and employment

Results in Figure 15 show that a vast majority of the participants (93%) were bachelor's degree students and the remaining 7% were doctoral degree students.

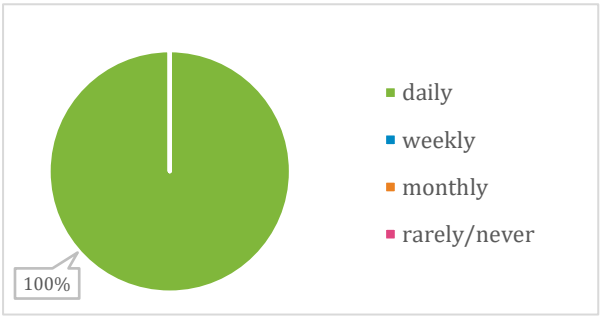

Figure 16: Participant's computer use

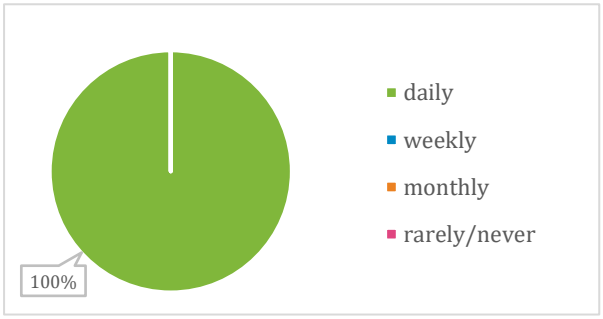

Figure 17: Participants' smart phone use

Results on **Figure 16** and Figure 17 are the same since all of the participants use both their smart phones and computers every day.

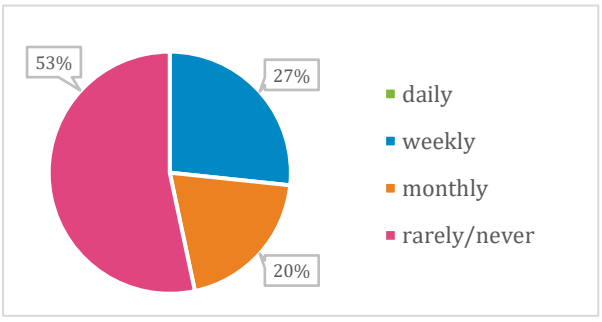

Figure 18: Participants' VR devices use (frequency)

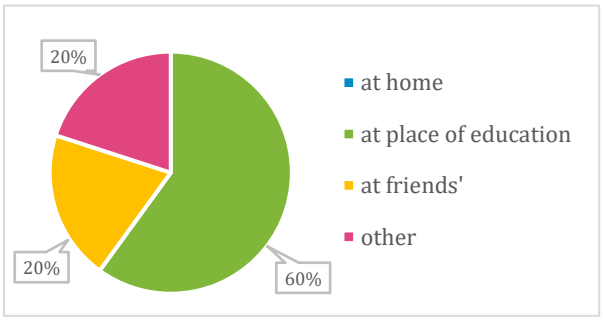

Figure 19: Participants' VR devices use (location)

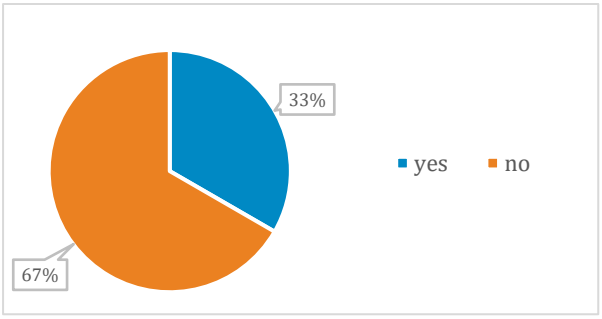

Figure 20: Previous VR sickness experience

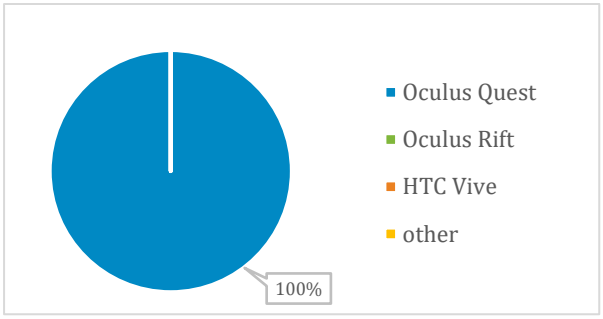

Figure 21: Share of used VR headsets during the experiment

The most frequent location where participants used VR devices' shown in Figure 19 is the educational institution (60%), then equally split with 20% each between friend's place and other locations. As none of the participants have a VR device at home results in Figure 18 are reasonable since more than half (53%) have never used a VR device before. While 20% use them on a monthly basis and 27% interact with them every week. Results shown in Figure 20 show that 67% have never experienced VR sickness. And all participants used the same VR device, Oculus Rift, see Figure 21.

2.2.2 User experience questionnaire results

The UEQ results, presented in Figure 22 show that the tested application Logic Gates was very well received by the participants and, that the Dynamic lists and sorting algorithms application was well accepted by the participating users.

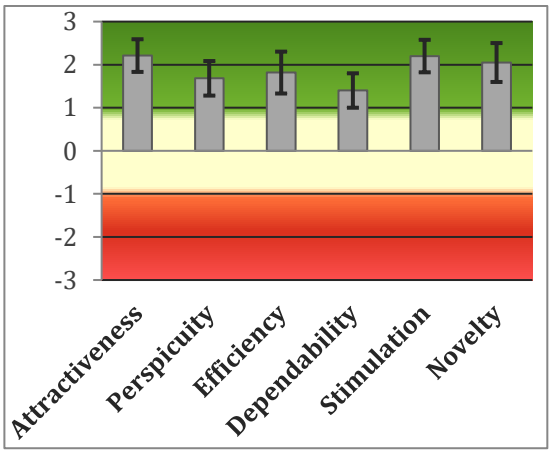

Figure 22: UEQ results for individual scales (Dynamic lists and sorting algorithms)

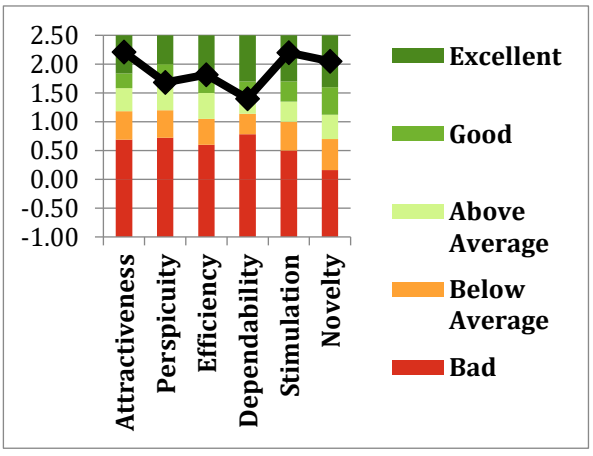

Figure 23: A benchmark comparison of UEQ results (Dynamic lists and sorting algorithms)

The participants scored the application very highly on all the scales, they found the application highly attractive with a score of 2.21, and the hedonic quality (Stimulation and Novelty scales) reached a score of 2.13 which are considered "excellent" results. The rest of the pragmatic scales (Perspicuity, Efficiency and Dependability) reached "above average" results with Dependability being the lowest scored scale. In comparison with other evaluated solutions seen in Figure 23 the confidence intervals are good and even excellent therefore making our conclusion for this application a positive one. The solution seems to have a pleasing design and a functional implementation for its users.

2.2.3 Simulator sickness questionnaire score

The SSQ evaluation has given some worrying results as the average values seem to be quite high, causing noticeable discomfort while using the VR application. This is especially true for oculomotor discomfort and feeling of disorientation, while nausea does not seem to have caused an impact. Similar conclusions can be reached from the free questions, where some participants have complained about eye strain and disorientation in space and time. A timed usage with sufficient breaks in-between sessions could help solve these problems. Results are represented in Table 2 and Figure 24Table 2: SSQ results and variance for the Dynamic lists and sorting algorithms application

SSQ Scales (Mean and Variance)		
Scale	**Average**	**SD**
SSQ-N	15.264	20.963
SSQ-O	37.395	27.099
SSQ-D	48.256	37.524
SSQ-T	37.400	29.245

Table 2: SSQ results and variance for the Dynamic lists and sorting algorithms application

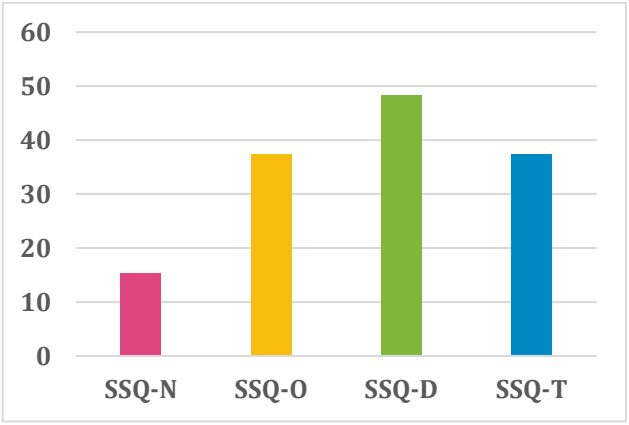

Figure 24: SSQ results for the "Dynamic lists and sorting algorithms" application

2.2.4 General comments and free evaluation feedback

The general impressions and comments from the evaluating participants were positive and they enjoyed the fun and unique experience of the presented solution in VR. They said it was versatile, refreshing and complimented the creativity of the project. Most of them would use the VR simulation again and some see promising ways to implement it in future studies and

learning. In comparison to traditional learning and training they commented it was more innovative, exciting, engaging, and interesting to use, but it still needs improvements as some of the users experienced negative side effects after prolonged use of the VR solution some examples being dizziness and blurring. The excitement and novelty of the VR simulation to the users is predictable as most of the participants haven't used VR before.

Most users didn't provide any ideas on how to improve the VR solution while some suggested including more options with additional gadgets and student-based subscriptions. Someone suggested installing more types of logic gates as well as making the circuits more real with some stimulation.

Overall, the "Logic Gates" application was positively received and it provides a fun and innovative way of learning with a good user experience.

2.3 Course: Digital Image Processing

The masters level course Digital Image Processing had 14 people evaluate their "Image Filtering" VR application. We will present the results of their evaluations in the following chapter. The results presented encompass their demographic profile, digital literacy, UEQ and SSQ results.

2.3.1 Information about participants

The first two figures represent the age and gender distribution of the participants. As we can tell from Figure 25 most of the evaluating participants (72%) are aged from 18 to 23 years old, followed by 21% of 24- to 29-year-olds with only 7% of the participants being older than 30. The gender distribution of participants in this group was completely even with half of them being female and half male as shown in Figure 26.

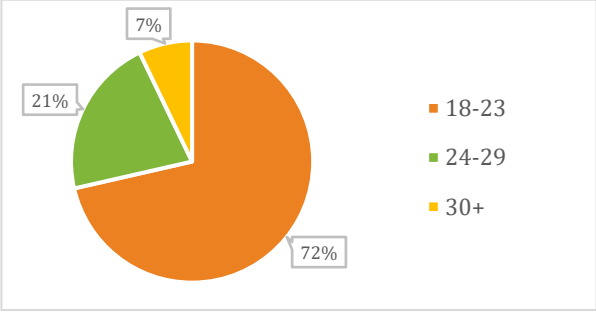

Figure 25: Participants' age distribution

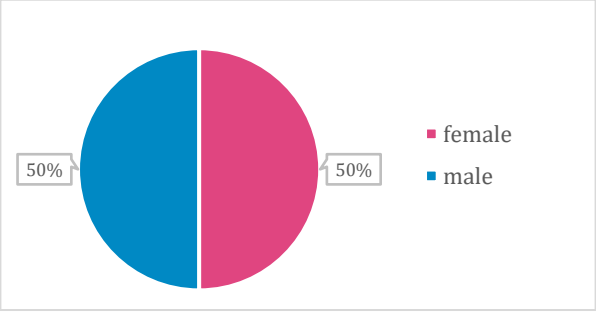

Figure 26: Participants' gender distribution

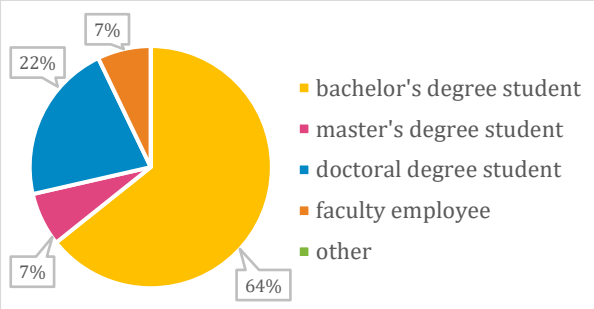

Figure 27: Participants' education and employment

Results in Figure 27 show that this group had a more diverse education and employment with more than half (64%) being bachelor's degree students. The next largest portion (22%) being doctoral degree students followed by equal percentages of faculty employees and master's degree students (7%).

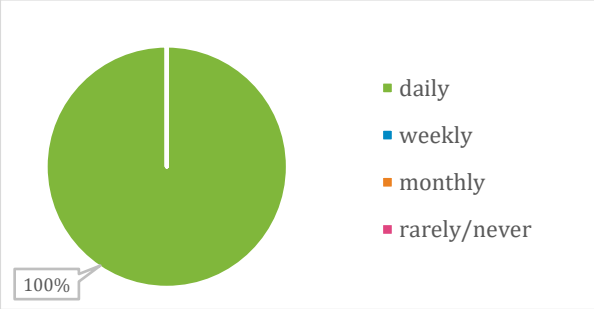

Figure 28: Participant's computer use

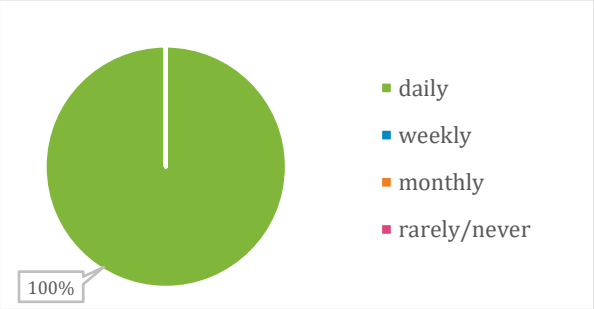

Figure 29: Participants' smart phone use

Results on Figures 28 and Figure 29 are the same since all of the participants use both their smart phones and computers every day.

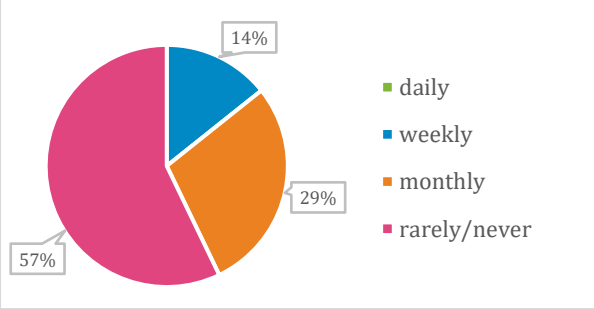

Figure 30: Participants' VR devices use (frequency)

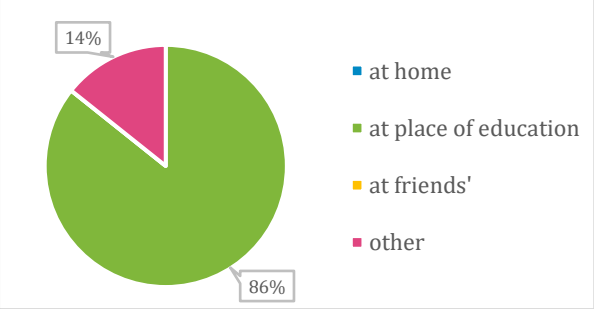

Figure 31: Participants' VR devices use (location)

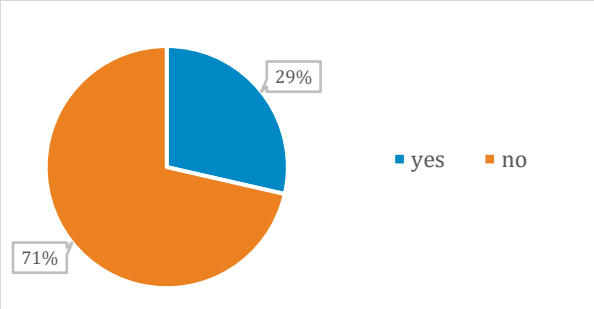

Figure 32: Previous VR sickness experience

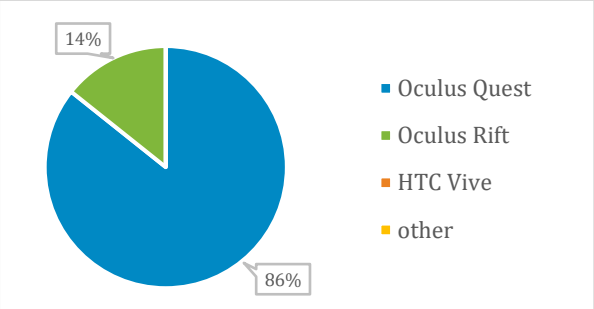

Figure 33: Share of used VR headsets during the experiment

The vast majority of the participants used the VR devices' as shown in Figure 31 at the educational institution (86%), with the remaining 14% using a VR device at other places. As none of the participants have a VR device at home results in Figure 30 are interesting since 14% of the participants still used VR devices on a weekly basis. More than half (57%) have never or rarely used VR devices before and the rest use them every month. Results shown in Figure 32 tell us that 71% have never experienced VR sickness. The main VR headset used by the participants was Oculus Quest (86%) and the rest used Oculus Rift show in Figure 33.

2.3.2 User experience questionnaire results

The UEQ results, presented in Figure 34 show that the tested application Image Filtering was very well received by the participants. They scored the application very highly on the hedonic scales, they found the application extremely attractive with a high score of 2.44, and the hedonic quality (Stimulation and Novelty scales) reached a score of 2.25 which are considered "excellent" results. The overall result of the pragmatic scales (Perspicuity, Efficiency and Dependability) was lowered by the Dependability score (1.02) making the pragmatic quality of the application "good" with a result of 1.43. Compared to other evaluated solutions seen in Figure 35 the confidence intervals are excellent on Attractiveness, Novelty and Stimulation, making the below average score of Dependability stand out. In our conclusion we think this VR application is visually already great, but it needs improvements on the dependability to reduce issues that cause problems for the user and make the whole experience of using the application even that much better.

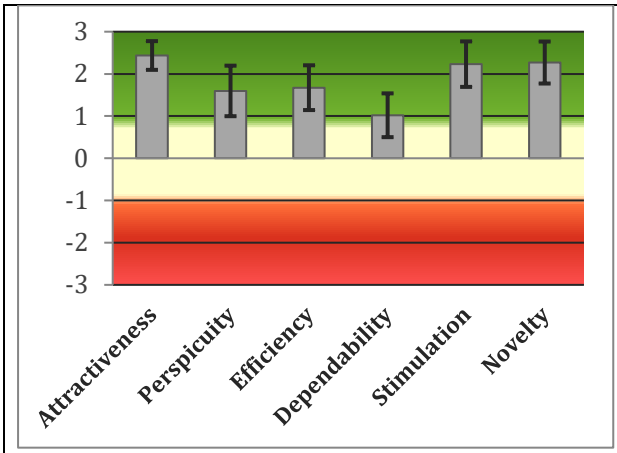

Figure 34: UEQ results for individual scales (Dynamic lists and sorting algorithms)

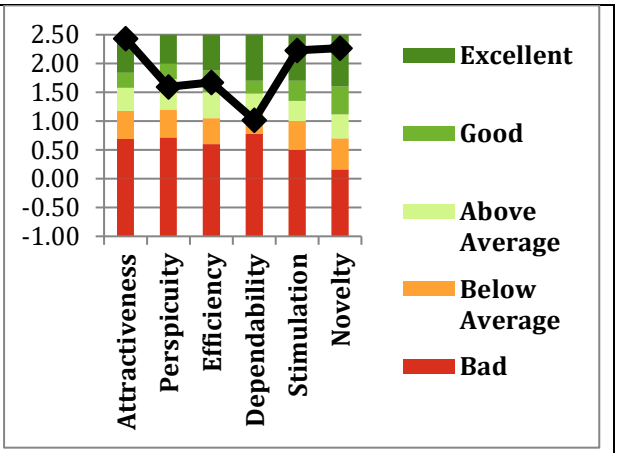

Figure 35: A benchmark comparison of UEQ results (Dynamic lists and sorting algorithms)

2.3.3 Simulator sickness questionnaire score

The SSQ evaluation has given interesting results as the average values seem to be quite high, causing higher levels of discomfort while using the VR application. This is especially true for oculomotor discomfort and feeling of disorientation, while nausea does not seem to have caused an impact shown in Table 3 and Figure 36.

SSQ Scales (Mean and Variance)		
Scale	**Average**	**SD**
SSQ-N	15,673	21,692
SSQ-O	37,900	17,336
SSQ-D	48,720	36,930
SSQ-T	37,934	24,889

Table 3: SSQ results and variance for the Dynamic lists and sorting algorithms application

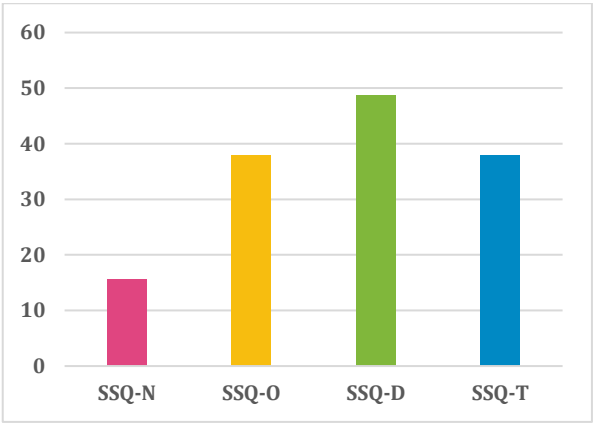

Figure 36: SSQ results for the "Dynamic lists and sorting algorithms" application

The results are consistent with the free questions as well where some participants mention feeling dizzy, difficulty focusing their eyes and having slight headaches. We suggest a timed usage with sufficient breaks in-between sessions (20 to 30 minutes) could help with reducing these problems.

2.3.4 General comments and free evaluation feedback

The general impressions and comments from the evaluating participants were positive and they complimented the image clarity and organization. The simplicity and ease of use was praised multiple times. Participants liked the creativity of the application. In comparison to traditional training, they found it clearer and more innovative, some said it was a better way of learning about image filtering. Most participants would use the application in the future and only experienced the VR related issues mentioned in the previous chapter. A few evaluators had issues with unclear instructions on how to use the VR headset, while others had no trouble at all. Other complaints were mostly about not being able to afford such equipment for home use and the heaviness od the VR headset, but these are unrelated to the application and therefore don't negatively impact its review.

The only suggestions for improvement of the VR applications were adding a tutorial on how to use the solution properly and improving the dependability of the application making it more responsive.

The overall response and review of the "Image Filtering" application was positive, it offers an interesting, easy to use way of learning and adds to the image clarity and differences between filters.

3 The University of Aleksandër Moisiu Durrës

The University of Aleksandër Moisiu Durrës (UAMD) participated in the project, their development team submitted 4 VR solutions intended for use in separate courses. The following courses' VR application were evaluated:

1. Fundamentals of Electrical Engineering course with the "Ohm`s Law" application
2. Data structures course with a "VRSort" application
3. Operating Systems course with the "Scheduling Algorithm" application
4. Multimedia Laboratory course with the "Introduction to Multimedia Equipment"

The evaluation results for each course and application are presented in the remainder of this section.

3.1 Course: Fundamentals of Electrical Engineering

The first of four submitted VR solutions from the UAMD that was developed during a bachelor's level course Fundamentals of Electrical Engineering had 14 evaluators that participated in the reviewing of the "Ohm's Law" application. We will present the demographic profile, digital literacy, UEQ and SSQ results of their evaluation in the remainder of this chapter.

3.1.1 Information about participants

We will present the age and gender distribution of the evaluators in the first two figures. The first Figure 37 all participants were between 18 and 23 years old. The gender distribution of the evaluators shown in Figure 38 had a higher number of males with 64% and the 34% of female participants.

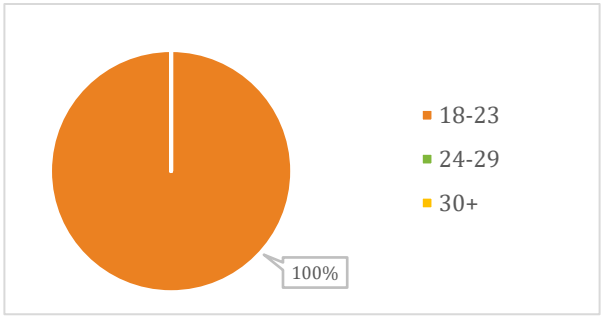

Figure 37: Participants' age distribution

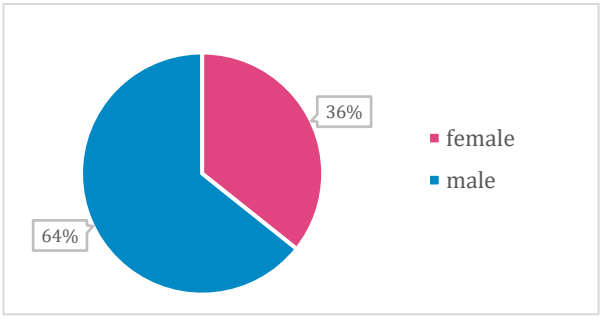

Figure 38: Participants' gender distribution

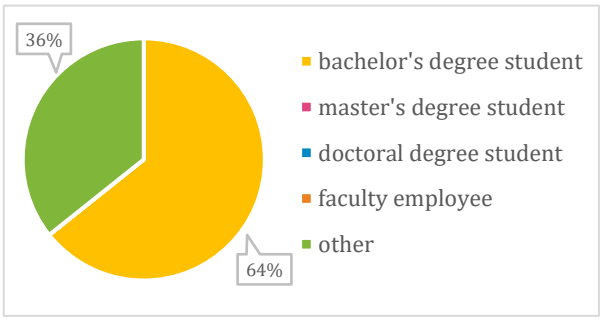

Figure 39: Participants' education and employment

Results in Figure 39 show that this group mainly consisted of bachelor's degree students (64%) with the remainder marking "other" as their education or employment.

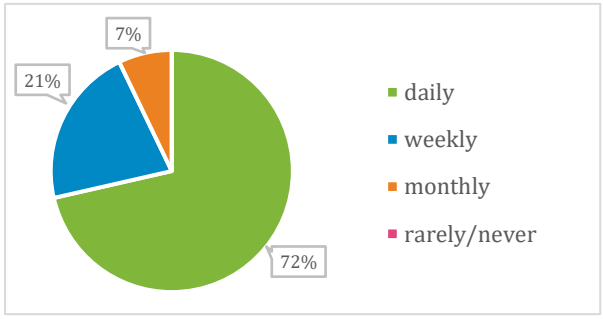

Figure 40: Participant's computer use

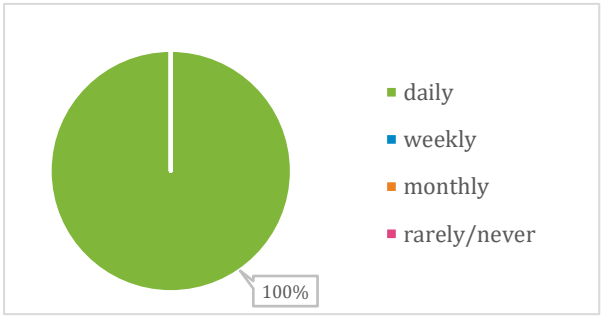

Figure 41: Participants' smart phone use

The results shown on Figure 40 are interesting as the majority use computers every day (72%), some weekly and there is a small number 7% that only use their computer monthly. Figure 41 shows that all the participants use their smart phone every day.

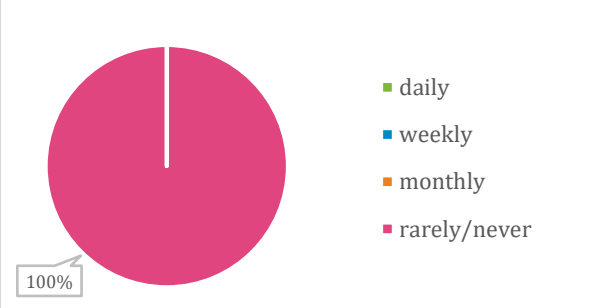

Figure 42: Participants' VR devices use (frequency)

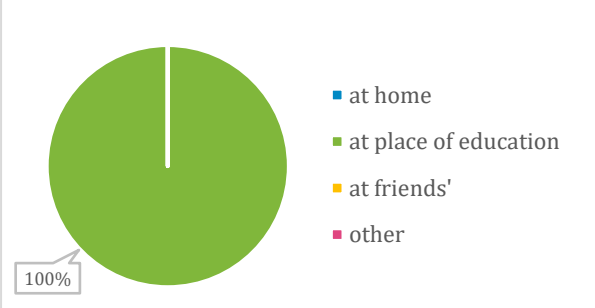

Figure 43: Participants' VR devices use (location)

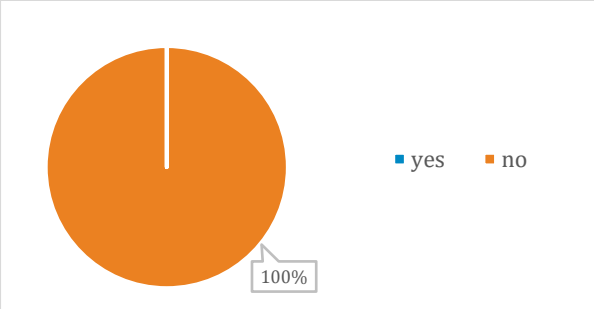

Figure 44: Previous VR sickness experience

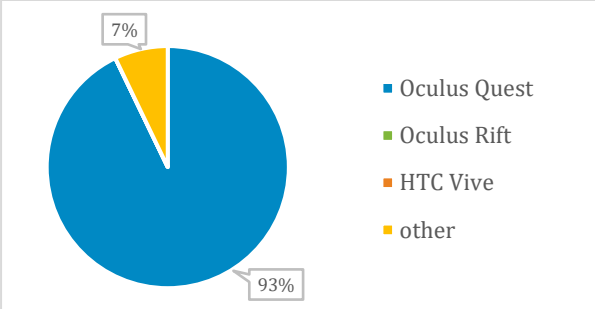

Figure 45: Share of used VR headsets during the experiment

Interestingly all the participants have rarely or never used a VR device before this study, shown in Figure 42. The results of Figure 43 make sense as all evaluators used VR devices at place of education so we can conclude it was probably during this study. None of the participants experienced VR sickness before, and they couldn't have if none of them used VR before, shown in Figure 44. 13 of the participants used the Oculus Quest VR headset while only one participant used a different "other" VR headset as we can see from Figure 45.

3.1.2 User experience questionnaire results

The UEQ results, presented in Figure 46 show that the tested application Ohm's Law was received extremely well by all participants. All scales reached high results with the lowest being Dependability but still reaching an "above average" score of 1.7. The overall result of the pragmatic scales (Perspicuity, Efficiency and Dependability) still reached a score of 2.26. They scored the application very highly on the hedonic scales, they found the application extremely attractive with a score of 2.70, and the hedonic quality (Stimulation and Novelty scales) reached a really high score of 2.87 which are considered "excellent" results. Compared to other evaluated solutions seen in Figure 47 the all the confidence intervals are excellent with the only exception with a good score being Dependability. Overall, the

application was extremely well received and the super high results can also be attributed to the small number of participants all of whom have never used a VR solution before. With the current results the application provides an excellent VR experience.

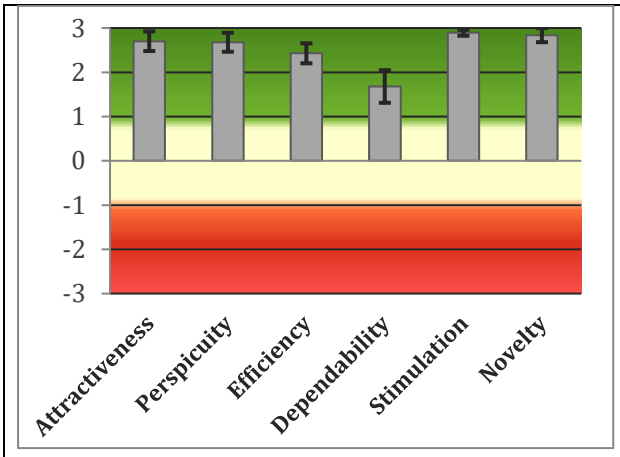

Figure 46: UEQ results for individual scales (Dynamic lists and sorting algorithms)

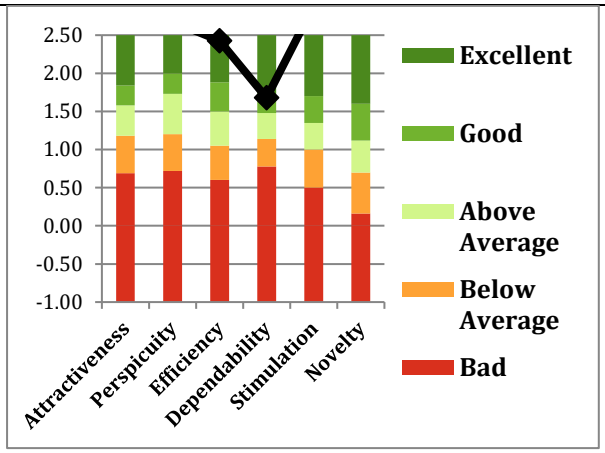

Figure 47: A benchmark comparison of UEQ results (Dynamic lists and sorting algorithms)

3.1.3 Simulator sickness questionnaire score

The SSQ evaluation shows interesting results in view of the previous high scored of the UEQ. Nausea does not seem to have caused much of an impact but the results of Figure 48 and Table 4 show there was some oculomotor discomfort and a bit more of feeling of disorientation. The results are interesting as only 3 participants mentioned having slight VR sickness side effects in the free questions. Overall results are still good as the total simulation sickness score (19.4) below 20.

SSQ Scales (Mean and Variance)		
Scale	Average	SD
SSQ-N	4.770	8.973
SSQ-O	16.243	17.553
SSQ-D	30.823	29.493
SSQ-T	18.166	19.398

Table 4: SSQ results and variance for the Dynamic lists and sorting algorithms application

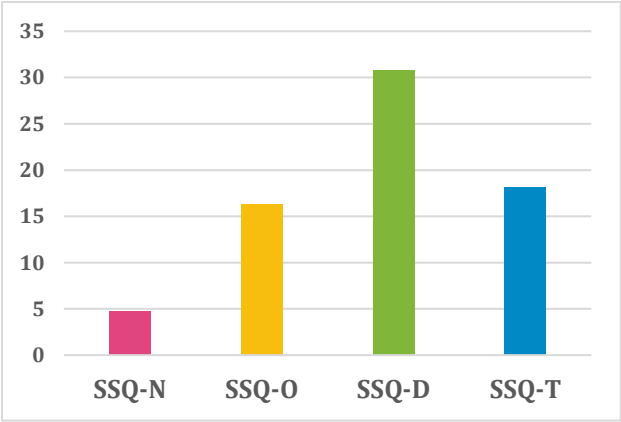

Figure 48: SSQ results for the "Dynamic lists and sorting algorithms" application

3.1.4 General comments and free evaluation feedback

The general impressions and comments from the evaluating participants were not too diverse as most found the application very interesting and liked the visual representation and its interactivity. All participants find the use of this VR solution compared to traditional learning very good and would use it again. They would like to see more options in the application, including more functions. Some evaluators also suggested using the solution in different subjects as well. Only three evaluators mentioned simulation sickness side effects.

The overall response and review of the "Ohm's Law" application was very positive, it offers an interesting and user-friendly VR experience.

3.2 Course: Data structures

UAMD's second VR solution "VRSort" application was developed during a bachelor's level course Data Structures. It had 16 evaluators that participated in providing feedback for the use of this VR solution. In the following chapter we will present the demographic profile, digital literacy, UEQ and SSQ results of their evaluation.

3.2.1 Information about participants

The first two figures represent the age and gender distribution of the evaluators. As seen in Figure 49 all participants were between 18 and 23 years old. The gender distribution between the evaluators is completely equal show in Figure 50 with half being female and the other half male.

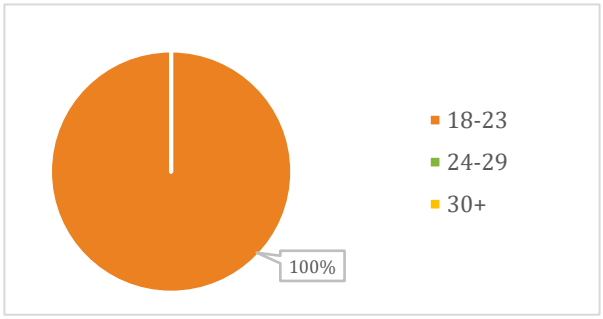

Figure 49: Participants' age distribution

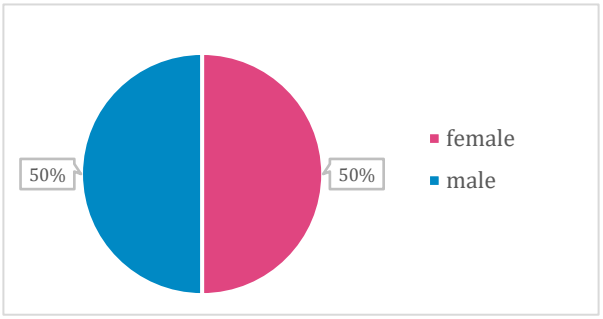

Figure 50: Participants' gender distribution

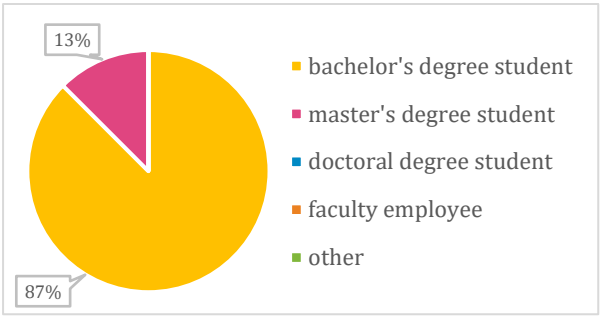

Figure 51: Participants' education and employment

Results in Figure 51 show that this group mainly consisted of bachelor's degree students (87%) with the remainder being master's degree students.

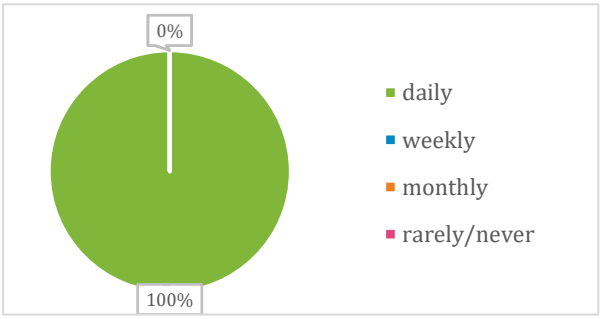

Figure 52: Participant's computer use

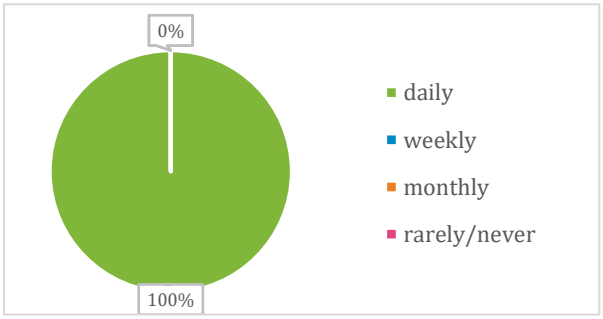

Figure 53: Participants' smart phone use

Both Figure 52 and Figure 53 show the evaluators use phones and computers daily.

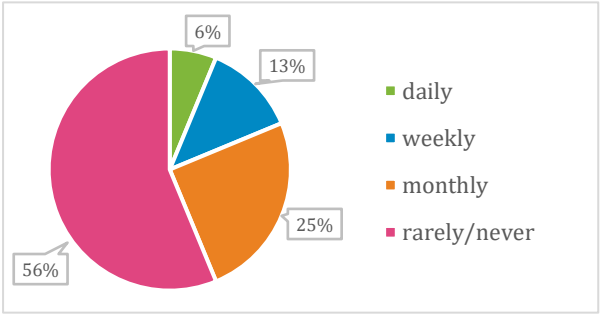

Figure 54: Participants' VR devices use (frequency)

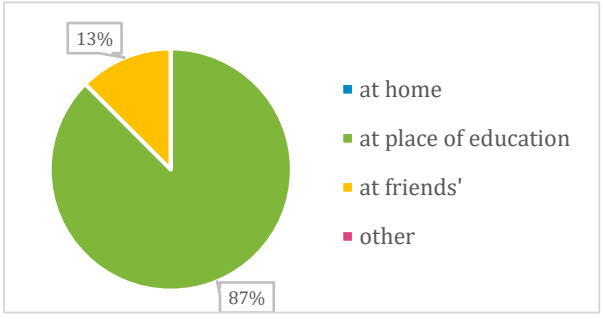

Figure 55: Participants' VR devices use (location)

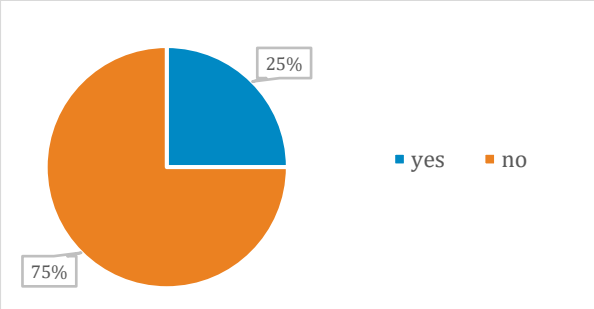

Figure 56: Previous VR sickness experience

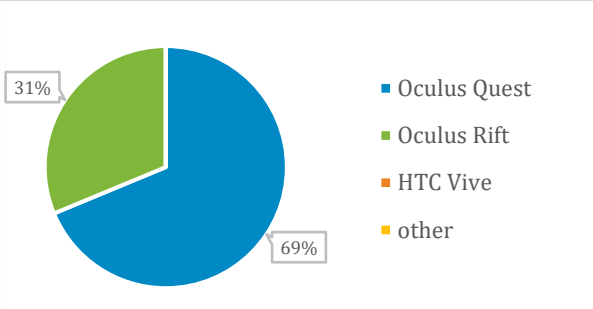

Figure 57: Share of used VR headsets during the experiment

The participants show a diverse use of VR devices seen in Figure 54 with more than half (56%) never or rarely having used a VR device. There is a larger portion (25%) of them that used VR monthly and 13% used VR weekly. There is even 6% of participants who use VR devices every day. Figure 55 shows that most of the participants (87%) used VR devices at place of education and 13% at friends' places. In previous experiences with VR headsets, they used them for playing games. As seen in Figure 56 a quarter of the users has experiences VR sickness before while the remainder haven't. The main VR headset used was Oculus Quest (63%) followed by Oculus Rift with 31%.

3.2.2 User experience questionnaire results

The UEQ results, presented in Figure 58 show that the tested application VRSort was received extremely well by all participants. All scales reached very high results. The highest score was for Stimulation with a 2.81 with the lowest being Dependability with a still "excellent" 1.98. With these results the scores of hedonic quality and Attractiveness were above 2.7, and a pragmatic quality of 2.4. Compared to other evaluated solutions seen in Figure 59 the all the confidence intervals are excellent. Overall, the application was extremely well received. We might get some differing results if a study was done with a larger number of evaluators with more diverse experiences. With the current results the application provides an excellent VR experience.

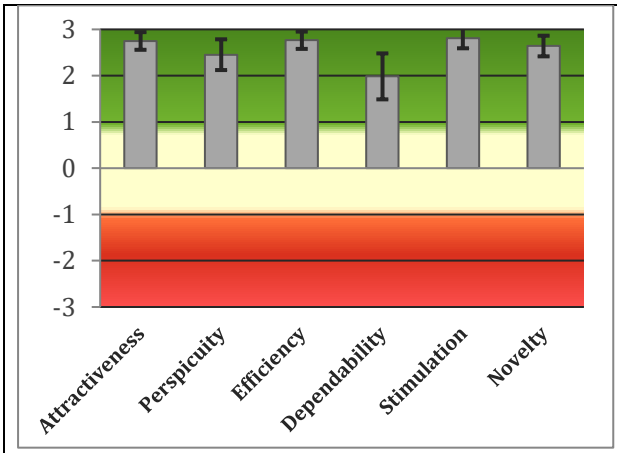

Figure 58: UEQ results for individual scales (Dynamic lists and sorting algorithms)

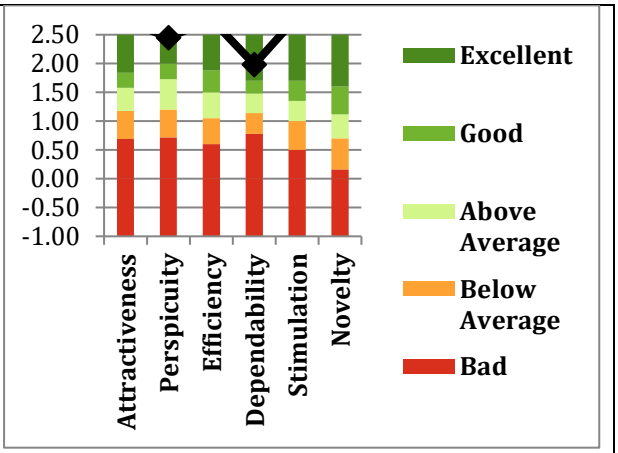

Figure 59: A benchmark comparison of UEQ results (Dynamic lists and sorting algorithms)

3.2.3 Simulator sickness questionnaire score

The SSQ evaluation seen in Figure 60 and Table 5 shows interesting results as the average scores are high for disorientation, oculomotor discomfort played a role while nausea did not reach high numbers. The results are interesting because the previous user experience scores were so high and in the free questions the participants only mention eye fatigue and lightheadedness once and there are no other mentions of any VR sickness side effects. The overall use of the VR solution might cause some problems but it is not too concerning.

SSQ Scales (Mean and Variance)		
Scale	**Average**	**SD**
SSQ-N	13.118	20.275
SSQ-O	20.845	22.401
SSQ-D	31.320	41.137
SSQ-T	23.843	27.614

Table 5: SSQ results and variance for the Dynamic lists and sorting algorithms application

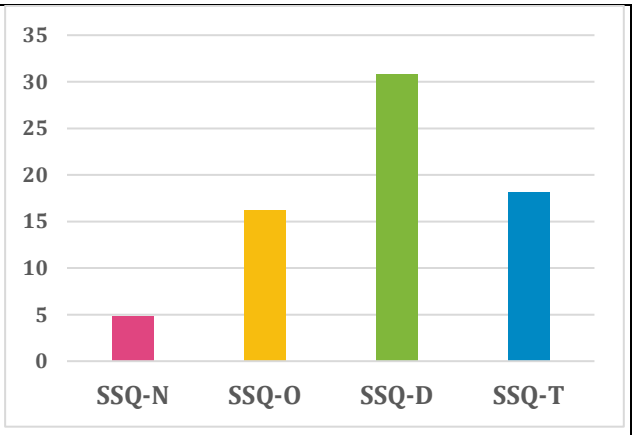

Figure 60: SSQ results for the "Dynamic lists and sorting algorithms" application

3.2.4 General comments and free evaluation feedback

The general impressions and comments from the evaluating participants were mostly positive stating that they found it interesting and the way the information was organized was understandable and simple some say practical. It explained ranking algorithms in a simple manner that was easier to understand in comparison to traditional training. They would all use it again and implement it in their learning. The only thing they disliked was the amount of information about the application that was difficult to understand for some users.

None of the participants had any suggestions or ideas on how to improve the solution.

The overall response and review of the "VRSort" application was very positive, it offers a simple and understandable way of learning and the VR user experience is pleasant.

3.3 Course: Operating Systems

During the bachelor's course Operating Systems, the developers at UAMD submitted a VR solution called "Scheduling Algorithm" application. The solution had 10 evaluators that participated in the reviewing of the application. The following chapter will present the demographic profile, digital literacy, UEQ and SSQ results of their evaluation.

3.3.1 Information about participants

We will present the age and gender distribution of the evaluators in the first two figures. As we can see in the Figure 61 all participants were between 18 and 23 years old. The gender distribution of the evaluators shown in Figure 62 shows 9 of the participants were male and only one female evaluated the VR solution.

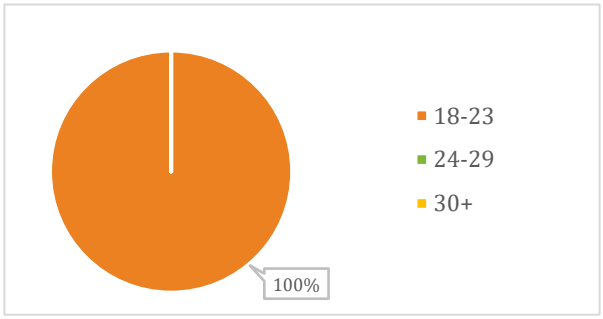

Figure 61: Participants' age distribution

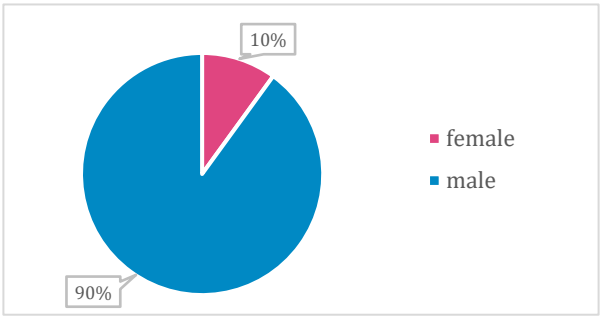

Figure 62: Participants' gender distribution

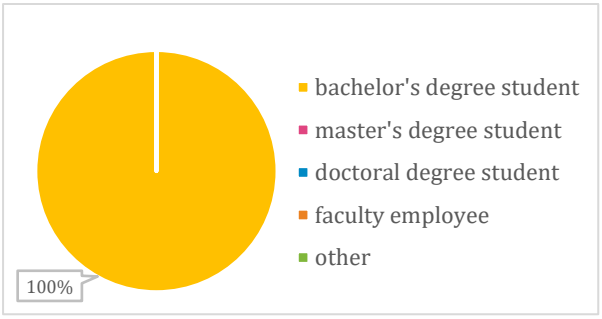

Figure 63: Participants' education and employment

Figure 63 shows that all participants in this group were bachelor's degree students.

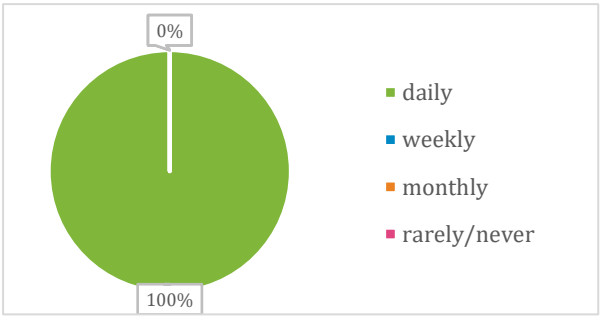

Figure 64: Participant's computer use

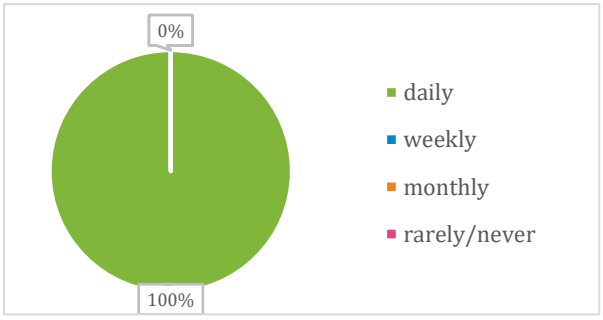

Figure 65: Participants' smart phone use

The results of Figure 64 and Figure 65 show that all the participants use their phones and computers every day.

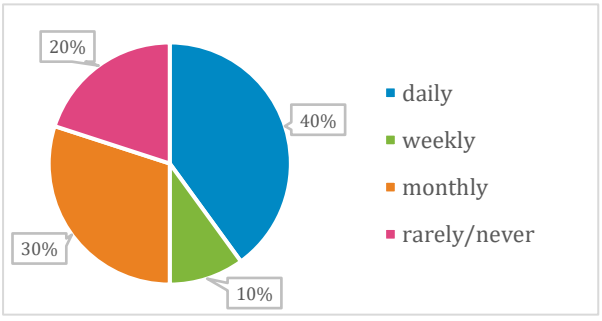

Figure 66: Participants' VR devices use (frequency)

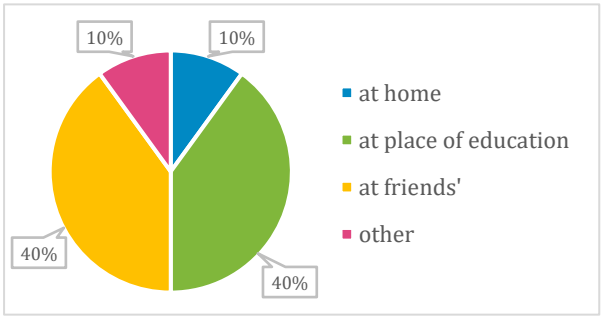

Figure 67: Participants' VR devices use (location)

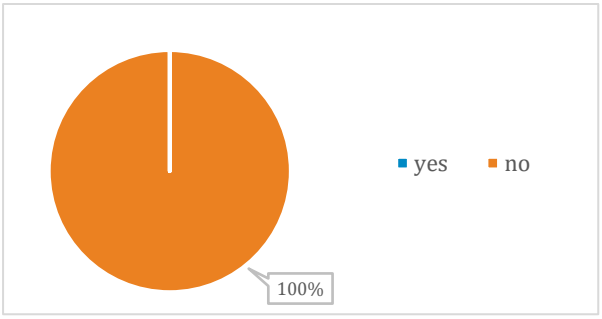

Figure 68: Previous VR sickness experience

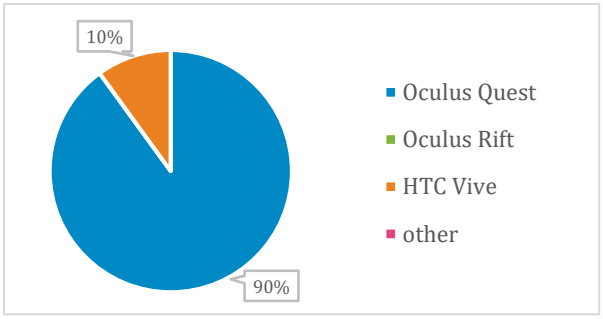

Figure 69: Share of used VR headsets during the experiment

The distribution of previous VR devices uses shown in Figure 66 shows that many use them daily (40%) closely followed by those that use them every month (30%). 20% never or rarely use VR while 10% interact with it weekly. The ones that use them regularly mention that it is for playing games and immersive third person experiences, one even used VR to shop for clothes. Figure 67 shows that 10% use VR devices at home and at other places. While the same number (40%) use them at place of education and at friends. None of the participants experienced VR sickness before shown in Figure 68 which is interesting as some use VR daily. Figure 69 shows 9 of the participants use the Oculus Quest VR headset and only one used the HTC Vive headset.

3.3.2 User experience questionnaire results

The UEQ results, presented in Figure 70 include consistent answers from 9 of the participants. They show that the tested application Scheduling Algorithm was received extremely well by all participants. All scales reached high results; their benchmark comparison score is excellent. The hedonic qualities (Stimulation, Originality) were scored with 2.61 and the Attractiveness was at a higher 2.78 score. The Pragmatic quality (Perspicuity, Efficiency, Dependability) is slightly lower with a score of 2.04. Compared to other evaluated solutions seen in Figure 71 the all the confidence intervals are excellent. The application was extremely well received and the super high results we might be able to attribute the high scores to such a small number of participants. We could get more conclusive and realistic results with more participants. With the current results the application provides an excellent VR experience.

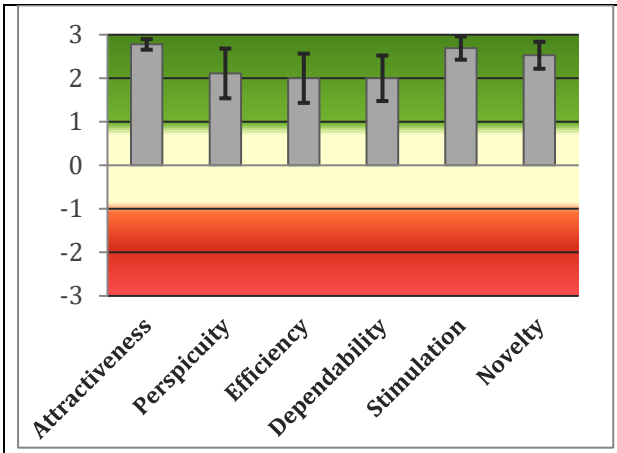

Figure 70: UEQ results for individual scales (Dynamic lists and sorting algorithms)

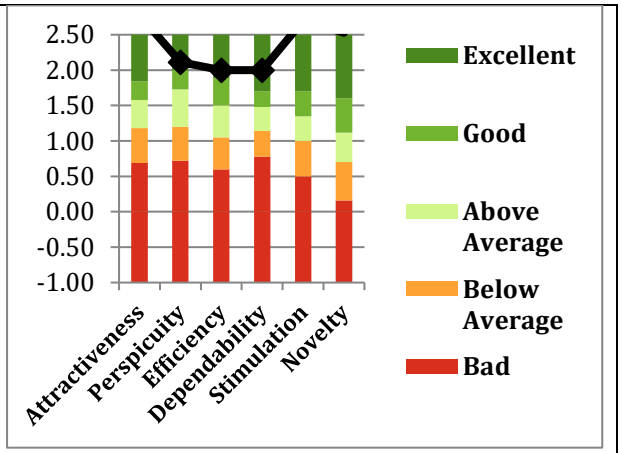

Figure 71: A benchmark comparison of UEQ results (Dynamic lists and sorting algorithms)

3.3.3 Simulator sickness questionnaire score

The SSQ evaluation shown in Table 6 and Figure 72 indicate that some participants experienced nausea, some evaluators had trouble with oculomotor discomfort and a bit more had a feeling of disorientation. While the answers of the free questions are different and only two of the participants mention feeling slight discomfort while using the VR solution. The scores are likely high due to a very small number of results making each small mark influence the whole scale more than it would if there were more evaluators and results.

SSQ Scales (Mean and Variance)		
Scale	Average	SD
SSQ-N	14.310	20.237
SSQ-O	17.434	16.394
SSQ-D	23.664	31.504
SSQ-T	20.570	21.826

Table 6: SSQ results and variance for the Dynamic lists and sorting algorithms application

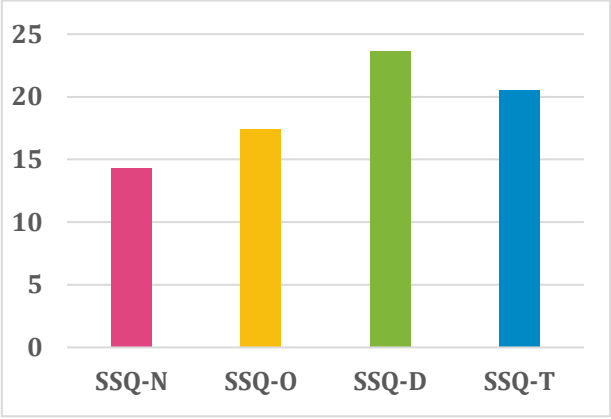

Figure 72: SSQ results for the "Dynamic lists and sorting algorithms" application

3.3.4 General comments and free evaluation feedback

The general impressions and comments from the evaluating participants were positive and most found the solution innovative with an involved experience that provided an interesting learning experience that motivated them to learn more than the traditional training. Some said it was fun and it provided with a new perspective for visualization. There were some requests for more involvement and interaction to help better understand the application. And one student mentioned feeling fatigue and headaches after prolonged use. All of the evaluators would use the VR application again. As previously mentioned, one participant asked for more interactivity in the solution but no other ideas on how to improve the solution were provided by the evaluators.

The overall response and review of the "Scheduling Algorithm" application was very positive, offering users a more involved and innovative VR user experience.

3.4 Course: Multimedia Laboratory

The last VR solution submitted by UAMD was developed during a Master's level course Multimedia Laboratory. The application "Introduction to Multimedia Equipment" was evaluated by 6 participants. In the following chapter we will present the demographic profile, digital literacy, UEQ and SSQ results of their evaluation.

3.4.1 Information about participants

The first two figures represent the age and gender distribution of the evaluators. As seen in Figure 73 most participants (83%) were between 18 and 23 years old. And 17% were aged 30 and older. The same distribution is true for the genders seen in Figure 74.

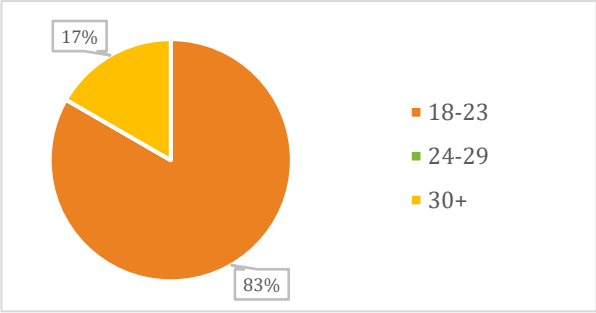

Figure 73: Participants' age distribution

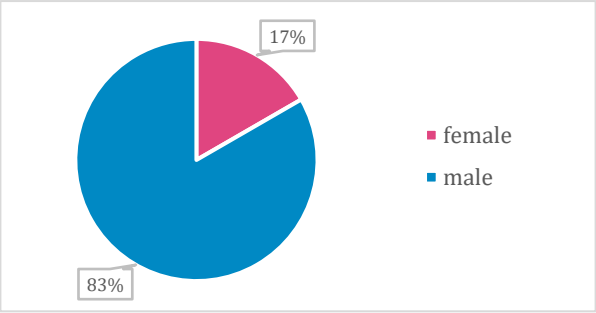

Figure 74: Participants' gender distribution

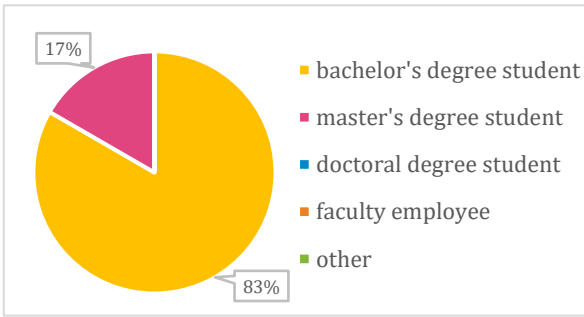

Figure 75: Participants' education and employment

Results in Figure 75 show that this group mainly consisted of bachelor's degree students (83%) with the remainder being master's degree students.

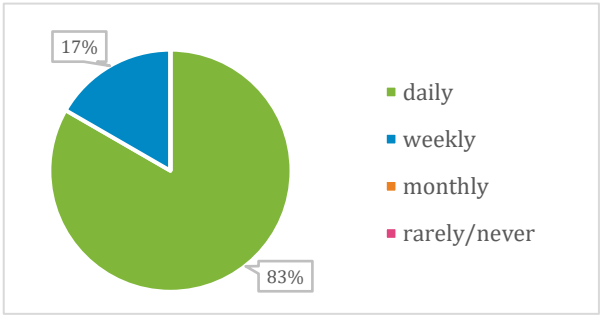

Figure 76: Participant's computer use

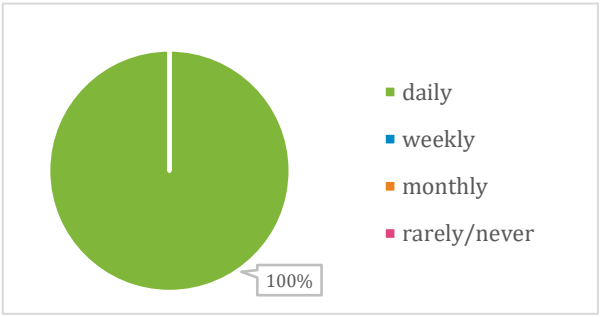

Figure 77: Participants' smart phone use

Figure 76 shows that most (83%) evaluators use their computers every day and some (17%) use it weekly. And all participants use their smart phones daily, shown in Figure 77.

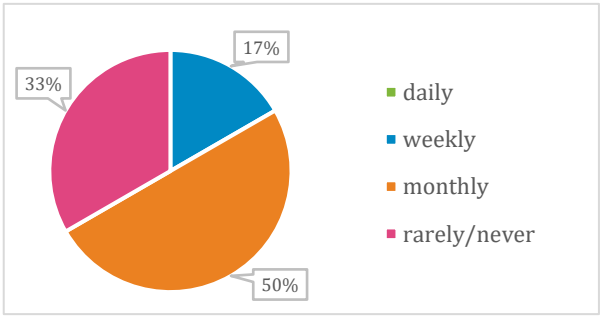

Figure 78: Participants' VR devices use (frequency)

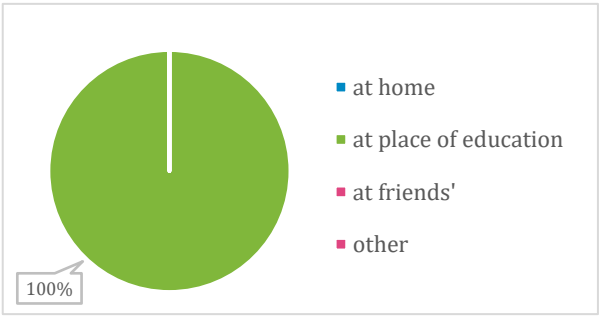

Figure 79: Participants' VR devices use (location)

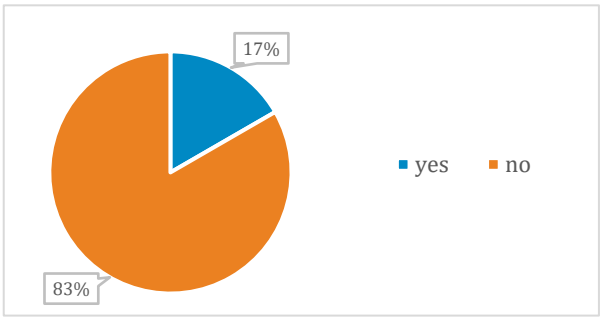

Figure 80: Previous VR sickness experience

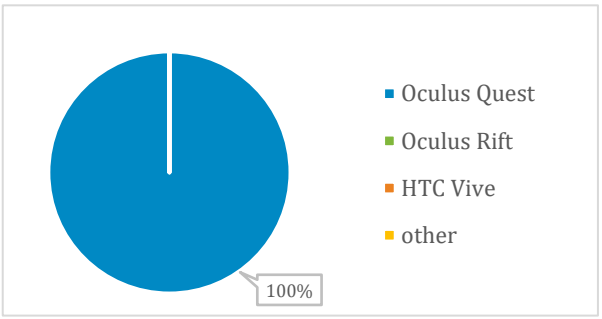

Figure 81: Share of used VR headsets during the experiment

Figure 78 shows that half of the participants use VR monthly, 33% have never or rarely used VR and 17 % use it weekly. All of them used VR devices at place of education as seen in Figure 79. The majority (83%) have never experienced VR sickness before and only 17% have. All of the evaluators used the Oculus Quest VR headset.

3.4.2 User experience questionnaire results

There were 6 evaluators that participated but only 5 provided consistent answers usable for the UEQ. The results, presented in Figure 82 show very high scores on all the scales. The Introduction to Multimedia Equipment application received great scores for attractiveness (2.83) and its pragmatic quality (Perspicuity, Efficiency, Dependability) received a score of 2.55. The lowest score was given for hedonic quality (Stimulation, Originality) at 2.30. The results are very good because the sample size was small and more samples would be required to reach more realistic results. Compared to other evaluated solutions seen in Figure 83 the all the confidence intervals are excellent. Overall, the application was extremely well received. With the current results the application provides an excellent VR experience.

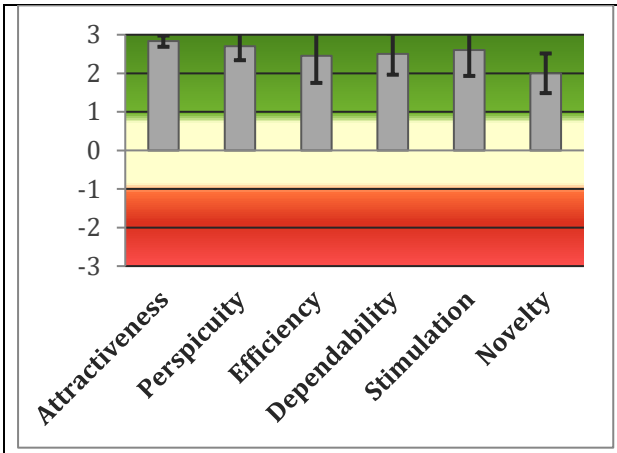

Figure 82: UEQ results for individual scales (Dynamic lists and sorting algorithms)

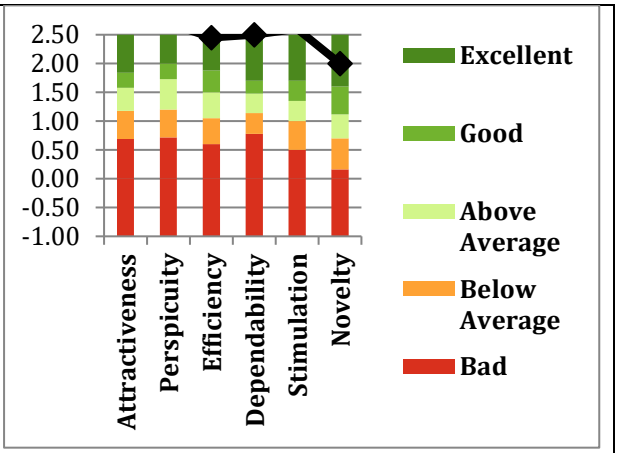

Figure 83: A benchmark comparison of UEQ results (Dynamic lists and sorting algorithms)

3.4.3 Simulator sickness questionnaire score

The SSQ evaluation seen in Figure 84 and Table 7 shows good results as the average scores are not high if we account for the low number of participants and how a small value can greatly influence the SSQ scale. There was a higher value for disorientation, and lower values for oculomotor discomfort, while nausea did not play a significant role. In the free questions one of the evaluators mentioned headaches and another slight dizziness. Overall use of the VR solution might cause slight disorientation, but results are still below the "bad simulation" threshold of 20.

SSQ Scales (Mean and Variance)		
Scale	Average	SD
SSQ-N	7.950	9.380
SSQ-O	13.897	11.157
SSQ-D	23.200	35.941
SSQ-T	16.207	18.117

Table 7: SSQ results and variance for the Dynamic lists and sorting algorithms application

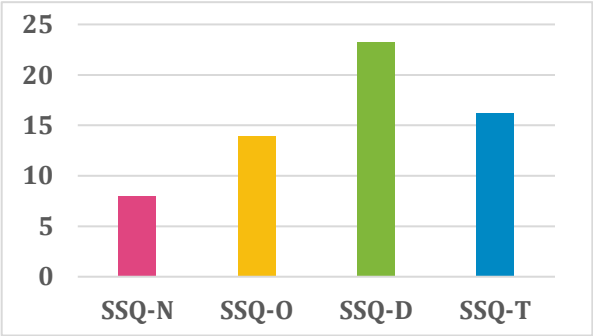

Figure 84: SSQ results for the "Dynamic lists and sorting algorithms" application

3.4.4 General comments and free evaluation feedback

The general impressions and comments on the VR Introduction to Multimedia Equipment from the evaluating participants were positive praising the exact layout of the laboratory in the simulation to the real one. They enjoyed the storytelling and new ideas that were combined into a nice VR experience. All of the participants liked the interesting VR solution and would use it again. Some of the evaluators mentioned there were too many colors for them and another complained the simulation caused slight headaches. The rest had no complaints. The participants suggested some improvements, adding real graphics to the simulation and more interactive objects, they wished for a longer experience and solving some teleportation issues.

The overall response and review of the “Introduction to Multimedia Equipment” application was very positive, it offers an interesting, interactive and innovative way of learning about multimedia equipment through the use of a VR device, with a pleasant user experience.

4 University of Prishtina

In the scope of the project University of Prishtina development team produced 7 VR solutions, each intended for its own course. The following courses' VR applications were evaluated:

1. Fundamentals of Electrical Engineering course with the "Electric and Magnetic Field" application
2. Digital Electronics course with the "Human - VR interaction" application
3. Electromagnetic Filed and Waves course with the "Electromagnetic field" application
4. Multimedia Communications course with the "VR equipment" application
5. Bio-medicinal Electronics course with the "COVID - 19 Detection" application

The 6th Master Thesis course with "Smart Home" application was not evaluated as one participant simply is not enough data to process and evaluate. And 7th course Digital Circuits course was not evaluated as we did not receive the submitted data.

The evaluation results for each course and application are presented in the remainder of this section.

4.1 Course: Fundamentals of Electrical Engineering

For the Fundamentals of Electrical Engineering course done on a bachelor's level the "Electric and Magnetic Field" application was developed and evaluated. There were 5 participating evaluators, whose demographic profile, digital literacy, UEQ and SSQ results are presented in the following chapter.

4.1.1 Information about participants

The demographic structure of the participating evaluators is presented in **Figure 85**-Figure 86. All participants were from the age group 18-23 years old. Women represented 40% of the participants and the remaining 60% of the participants were males.

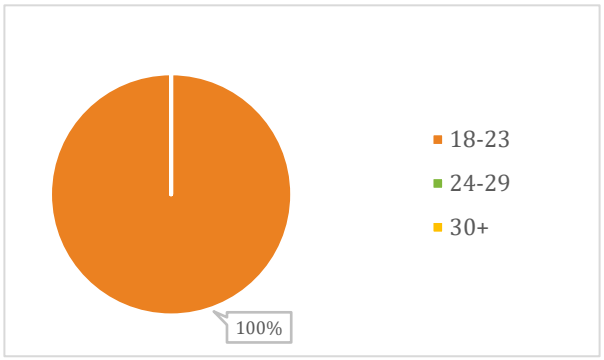

Figure 85: Participants' age distribution

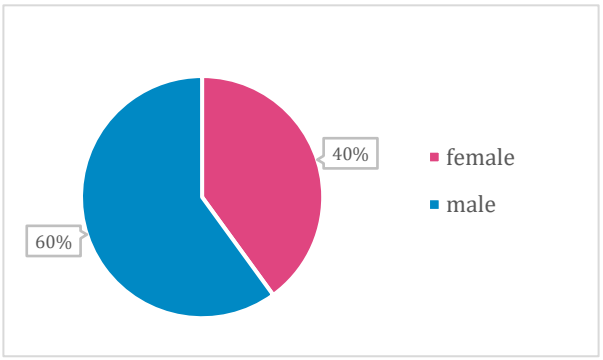

Figure 86: Participants' gender distribution

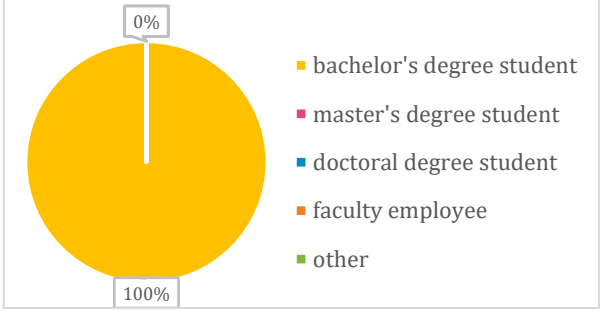

Figure 87: Participants' education and employment

Their education and employment was completely homogenous as all of the participants were bachelor's degree students as seen in Figure 87.

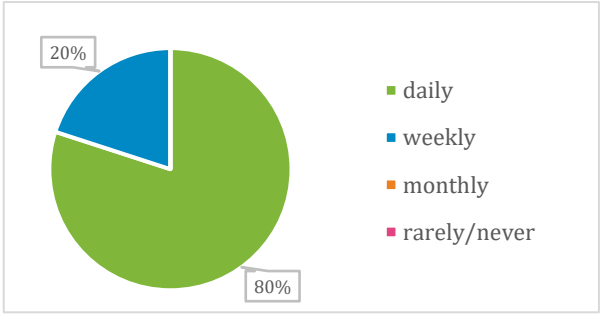

Figure 88:Participant's computer use

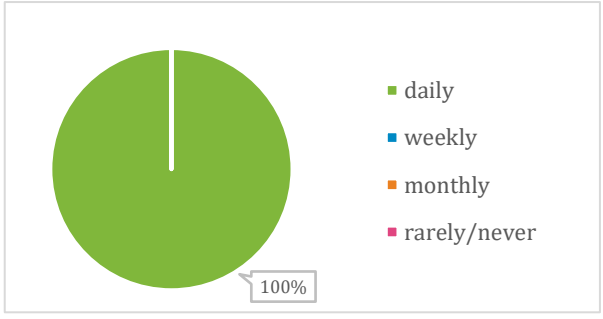

Figure 89:Participants' smart phone use

All the participants use their mobile devices daily, with 80% of them also reporting a daily use of the personal computer, the other 20% use it on a weekly basis, as seen in **Figure 88**Figure 89.

Usage of VR devices shown in Figure 90 is expectedly not very frequent as 60% of the participants have rarely or never used a VR device before the evaluation. Monthly users of VR devices represent 20% of the participants and 20% represent weekly users of these devices. It is conclusive that Figure 91 shows similar results use at place of education was done by 60%, while 20% of the evaluators used them at friend's and the rest at other places.

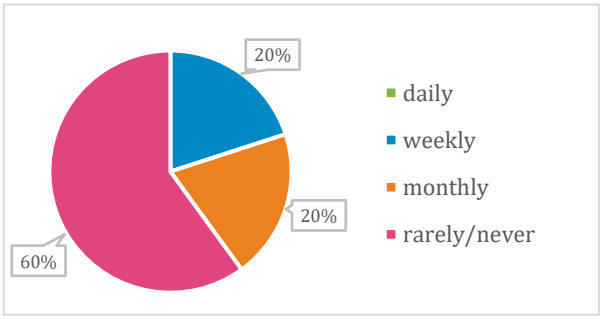

Figure 90: Participants' VR devices use (frequency)

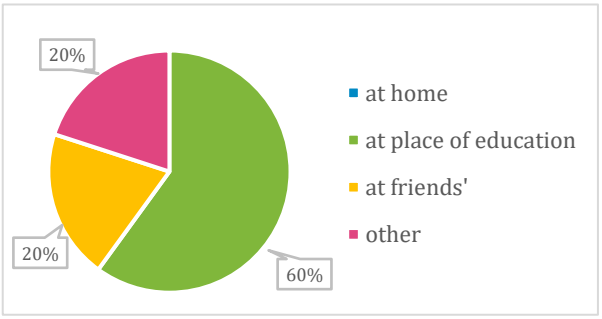

Figure 91: Participants' VR devices use (location)

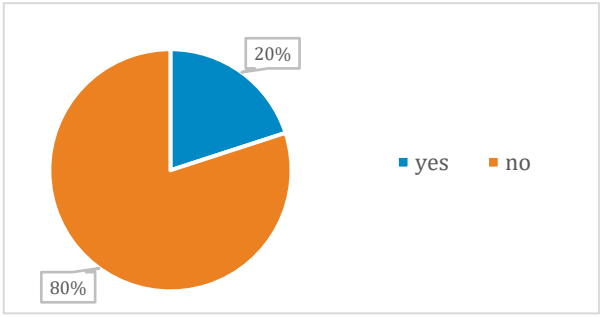

Figure 92: Previous VR sickness experience

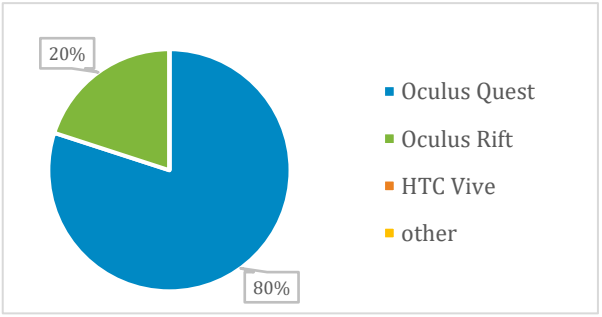

Figure 93: Share of used VR headsets during the experiment

Figure 92 shows that 80% have never experienced VR sickness, which is a higher number than the people who have never or rarely used such a solution. Finally, the major share of VR devices used during the evaluation goes to Oculus Quest (80%), with Oculus Rift representing the other 20%, shown in Figure 93.

4.1.2 User experience questionnaire results

Out of the 5 participants' UEQ results received only 2 were conclusive enough to use. After removing the problematic data patterns, we did not have a sufficient sample to present and evaluate the UEQ results for the "Electric and Magnetic Field" application.

4.1.3 Simulator sickness questionnaire score

The SSQ evaluation has given some interesting results as the average values seem to be rather high, causing noticeable discomfort while using the VR application. This can probably be attributed to the small number of participating evaluators, causing each minor variation in answers to greatly influence the final scores. Oculomotor discomfort and feeling of disorientation caused discomfort, while nausea does not seem to have caused an impact. Results are represented in Table 8 and Figure 94. The total simulator sickness score seems high and can be atributed to a small sample size.

SSQ Scales (Mean and Variance)		
Scale	Average	SD
SSQ-N	19.080	27.814
SSQ-O	28.804	19.620
SSQ-D	38.976	37.351
SSQ-T	32.164	29.756

Table 8: SSQ results and variance for the Dynamic lists and sorting algorithms application

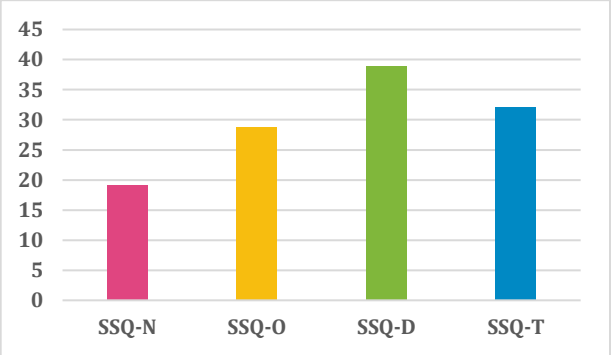

Figure 94: SSQ results for the "Dynamic lists and sorting algorithms" application

4.1.4 General comments and free evaluation feedback

General feedback from the evaluating participants was positive, praising the interesting and detailed questions posed in a clear way that was easy to understand. Compared to traditional training they found it very different and attractive, creative and even easier to understand. There were generally no complaints one person mentioned that the number of questions posed was too high. All of the participants would use the VR application again and no one mentioned having any VR sickness side effects which is interesting compared to the results of the previous chapter where we reached higher numbers at SSQ-T. There was only a suggestion to make the application usable for people with dioptric glasses, but that is on the hardware side of the glasses and not an application side improvement.

In general, the "Electric and Magnetic Field" application was well accepted.

4.2 Course: Digital Electronics

The second VR solution submitted by University of Prishtina was developed during a bachelor's level course Digital Electronics. The application "Human - VR interaction" was evaluated by 10 participants. In the following chapter we will present the demographic profile, digital literacy, UEQ and SSQ results of their evaluation.

4.2.1 Information about participants

The first two figures represent the age and gender distribution of the evaluators. As seen in Figure 95 most participants (90%) were between 18 and 23 years old. And 10% were aged between 24 and 29. There were 60% of female evaluators while the remaining 40% were male participants as seen in Figure 96.

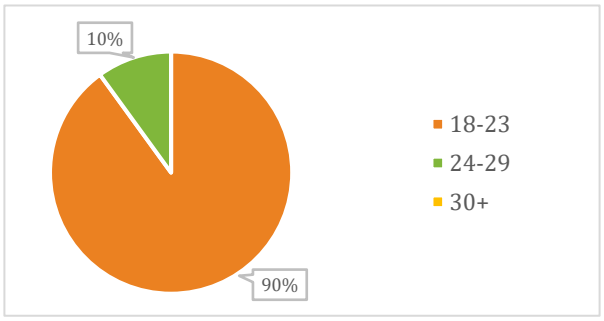

Figure 95: Participants' age distribution

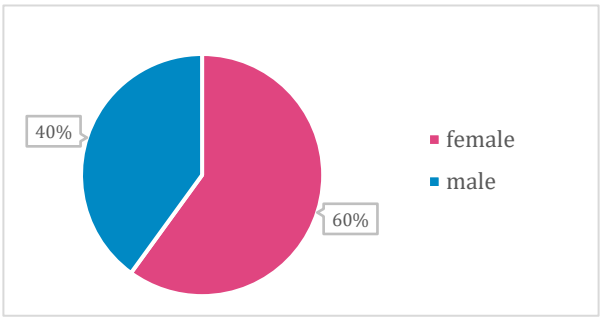

Figure 96: Participants' gender distribution

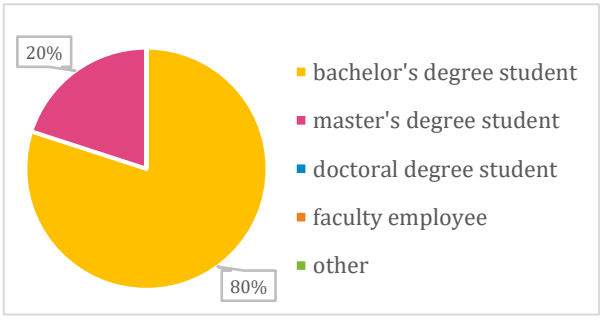

Figure 97: Participants' education and employment

Results in Figure 97 show that this group mainly consisted of bachelor's degree students (80%) with the remainder being master's degree students.

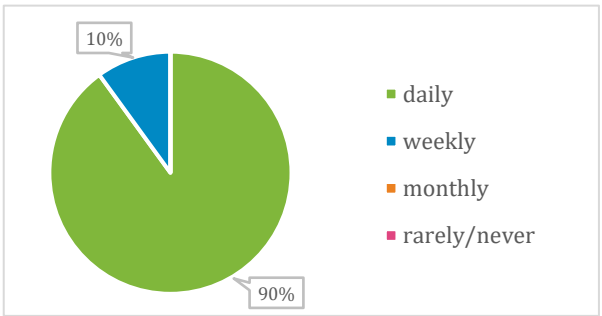

Figure 98: Participant's computer use

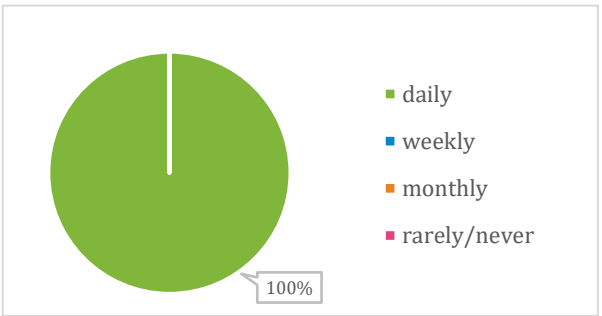

Figure 99: Participants' smart phone use

Figure 98 shows that most (90%) evaluators use their computers every day and some (10%) use it weekly. And all participants use their smart phones daily, shown in Figure 99.

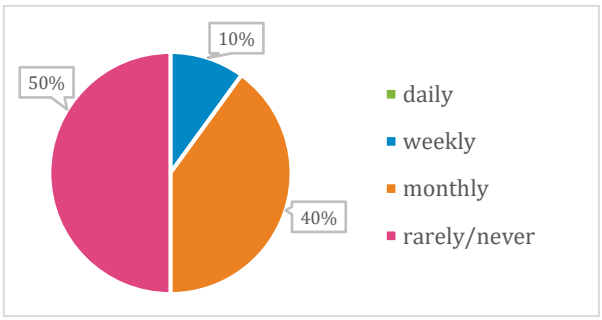

Figure 100: Participants' VR devices use (frequency)

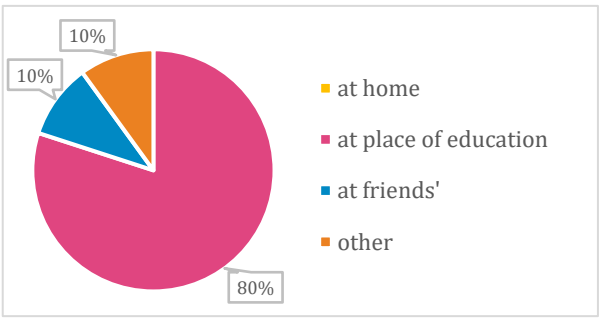

Figure 101: Participants' VR devices use (location)

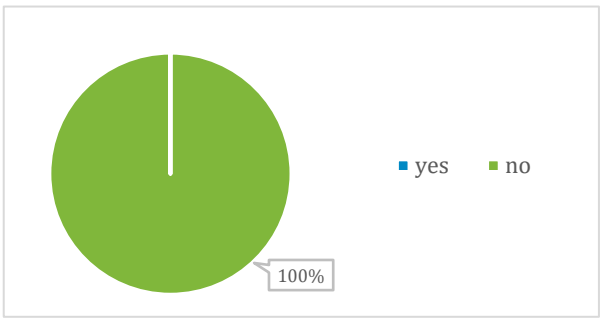

Figure 102: Previous VR sickness experience

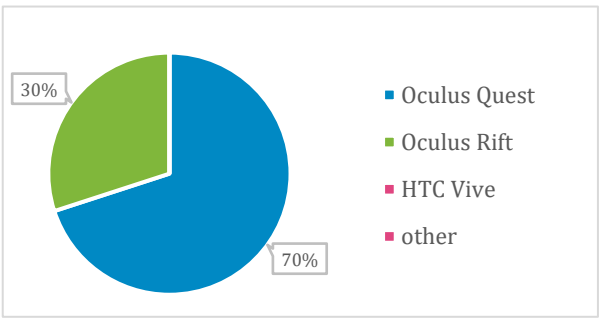

Figure 103: Share of used VR headsets during the experiment

Figure 100 shows that half of the participants have rarely or never used VR, 40% have used it monthly and the last 10% use it weekly. A majority (80%) used VR devices at place of education as seen in Figure 101. Some (10%) used VR devices at friend's and the rest at other places. None of the evaluators have ever experienced VR sickness before, seen in Figure 102. Most evaluators (70%) used the Oculus Quest VR headset while the rest used Oculus Rift, shown in Figure 103. They all enjoyed their previous VR experiences and found them interesting and exciting.

4.2.2 User experience questionnaire results

There were 10 evaluators that participated out of which 8 provided consistent answers usable for the UEQ. The results, presented in Figure 104 show very high levels on all the scales. The Human - VR interaction application received great scores for attractiveness (2.53) and its pragmatic quality (Perspicuity, Efficiency, Dependability) received a score of 2.07. A very similar score was given for hedonic quality (Stimulation, Originality) at 2.09. The results are very good because the sample size was small, and more samples would be required to reach more realistic numbers. Compared to other evaluated solutions seen in Figure 105 the confidence intervals for attractiveness, efficiency, dependability, and stimulation are excellent, while perspicuity and novelty reached good values. Overall, the application was well received. With the current results the application provides a great VR experience.

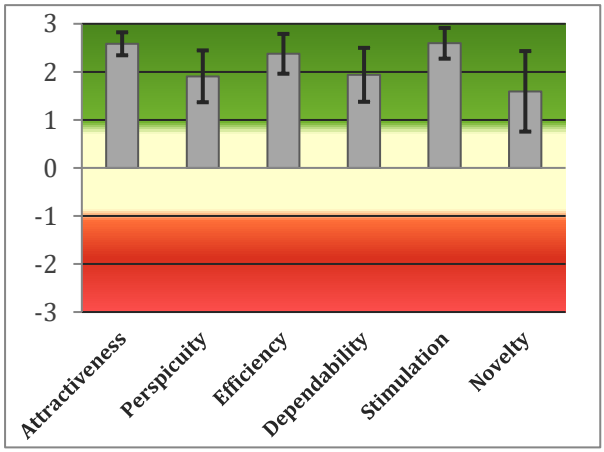

Figure 104: UEQ results for individual scales (Dynamic lists and sorting algorithms)

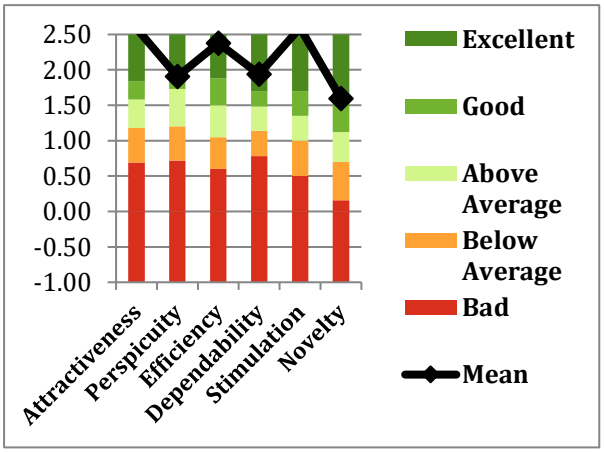

Figure 105: A benchmark comparison of UEQ results (Dynamic lists and sorting algorithms)

4.2.3 Simulator sickness questionnaire score

The SSQ evaluation seen in Figure 106 and Table 9 shows good results as the average scores are not high if we account for the low number of participants and how a small value can greatly influence the SSQ scale. There was a higher value for disorientation, and lower values for oculomotor discomfort, while nausea was barely noticeable. In the free questions one of the evaluators mentioned having headaches in the beginning while none of the others complain about any VR sickness side effects. Overall, the results are still below the "bad simulation" threshold of 20.

SSQ Scales (Mean and Variance)		
Scale	Average	SD
SSQ-N	5.724	10.255
SSQ-O	18.192	13.931
SSQ-D	22.272	14.964
SSQ-T	17.204	11.317

Table 9: SSQ results and variance for the Dynamic lists and sorting algorithms application

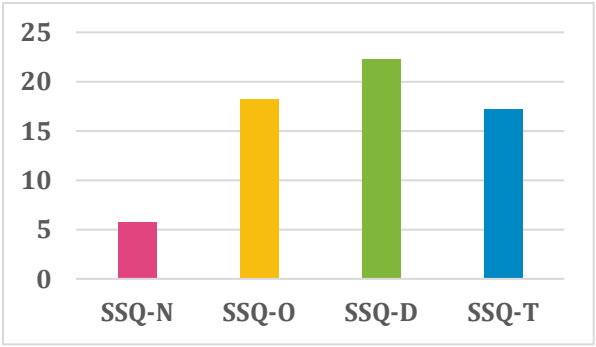

Figure 106: SSQ results for the "Dynamic lists and sorting algorithms" application

4.2.4 General comments and free evaluation feedback

The general impressions and comments on the Human - VR interaction application from the evaluating participants were positive. They found it interesting, motivating and enjoyed the transition from the real world into a virtual one. They liked having the option to choose between different formats. One evaluator mentioned that they would have liked to have more explanations and instructions on how to use the application, while no one else had any complaints. Compared to traditional training they found it more fun and exciting to use, the novelty made it easier to follow and learn. All of them would use the solution again and as mentioned in the previous SSQ evaluation only one evaluator had some headaches at the beginning of use of the VR solution. One evaluator suggested creating more VR applications for conquering user fears (fear of heights, public speaking, insects), there were no further suggestions on how to improve this solution.

The overall response and review of the "Human - VR interaction" application was very positive, it offers an interesting, exciting, and fun way of learning, with a pleasant user experience.

4.3 Course: Electromagnetic Field and Waves

During the bachelor's course Electromagnetic Filed and Waves the developers at University of Prishtina submitted a VR solution called "Electromagnetic field" application. The solution had 7 evaluators that participated in the reviewing of the application. The following chapter will present the demographic profile, digital literacy, UEQ and SSQ results of their evaluation.

4.3.1 Information about participants

We will present the age and gender distribution of the evaluators in the first two figures. As we can see in the **Figure 107** all participants were between 18 and 23 years old. The gender distribution of the evaluators shown in Figure 108 shows 43% of the participants were female and 57% were male.

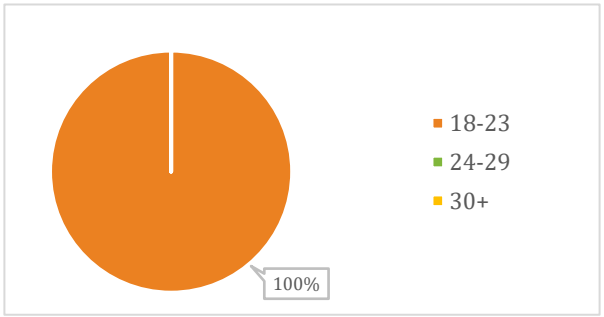

Figure 107: Participants' age distribution

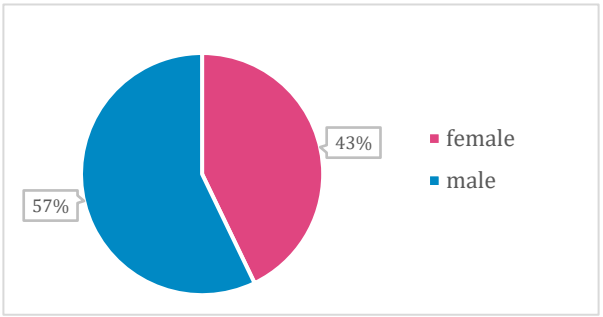

Figure 108: Participants' gender distribution

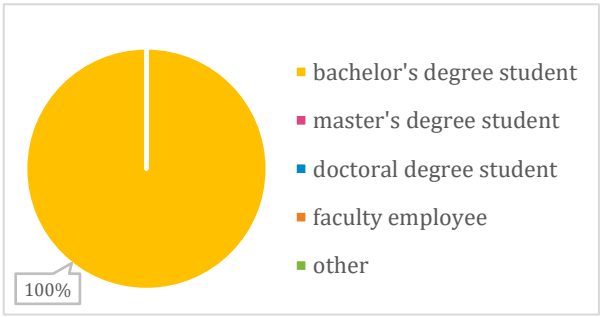

Figure 109: Participants' education and employment

Figure 109 shows that all participants in this group were bachelor's degree students.

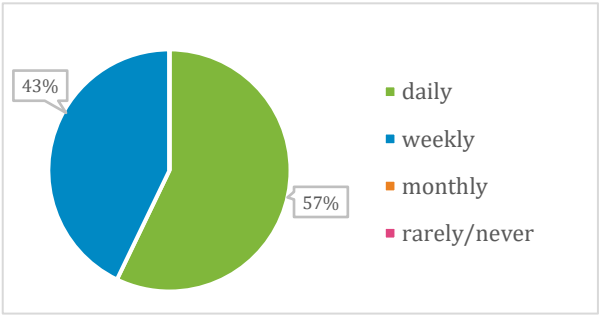

Figure 110: Participant's computer use

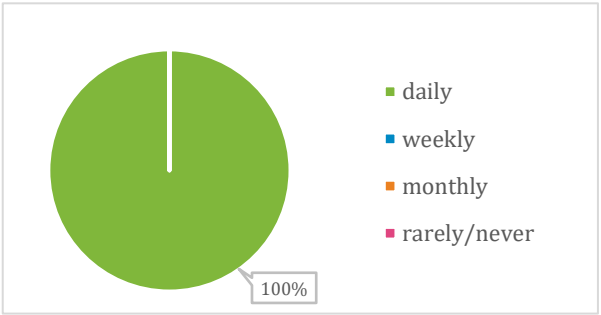

Figure 111: Participants' smart phone use

The results of Figure 110 show more than half of the participants use their computers ever day while 43% use them on a weekly basis. Figure 111 tells us that all the participants use their phones every day.

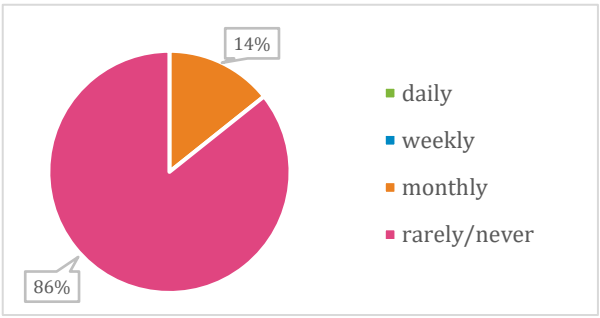

Figure 112: Participants' VR devices use (frequency)

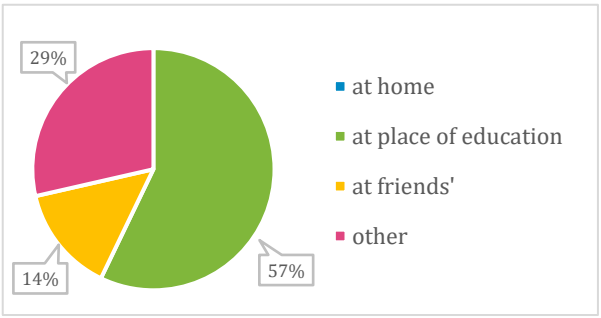

Figure 113: Participants' VR devices use (location)

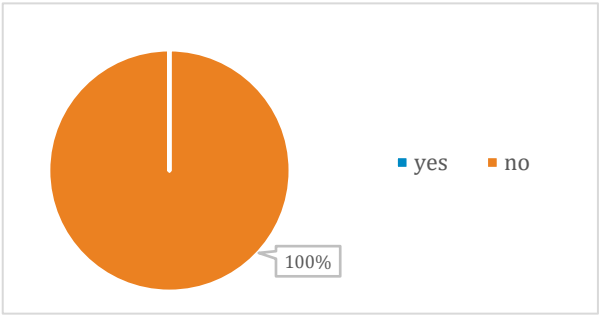

Figure 114: Previous VR sickness experience

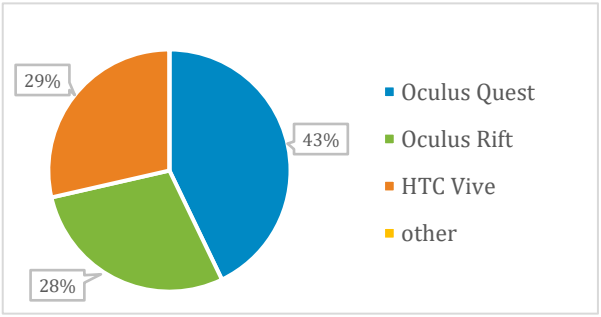

Figure 115: Share of used VR headsets during the experiment

The distribution of previous VR device use shown in Figure 112 shows that most of the evaluators have rarely or never used them before while the remaining 14% used them

monthly. Figure 113 shows that more than half (57%) of the participants used them at place of education, 14% use VR devices at friend's and the remainder at other places. None of the participants experienced VR sickness before shown in Figure 114. Figure 115 shows Oculus Quest was the main VR headset used by 43% of the evaluators followed equally by 29% with HTC Vive VR headset and 28% with Oculus Rift VR headset.

4.3.2 User experience questionnaire results

The UEQ results, presented in Figure 116 include consistent answers from 6 of the 7 participants. They show that the tested application Electromagnetic Field was quite poorly by the evaluators. All scales reached very low results, their benchmark comparison score shown in Figure 117 is mostly bad with three "bad" and two "below average" results. The hedonic qualities (stimulation, originality) were scored with 0.33 and the attractiveness was slightly higher with a score of 0.58. The Pragmatic quality (Perspicuity, Efficiency, Dependability) got a score of 0.50. Compared to other evaluated applications the results of the benchmark were as previously mentioned bad. Attractiveness, efficiency, dependability and stimulation fall under "bad" (in range of the 25% worst results), while perspicuity and novelty received "below average" results. The application was poorly received and evaluated if we look at these scores. The results are very much in contrast with the free questions asked in the end of the study where the evaluators seemed to enjoy the application and liked it in comparison to traditional training. With the current results the application seems to provide a bad VR experience, but these results should be interpreted with caution, due to a small sample of respondents, very high answer distribution and therefore possible misunderstanding of UEQ questions by some participants.

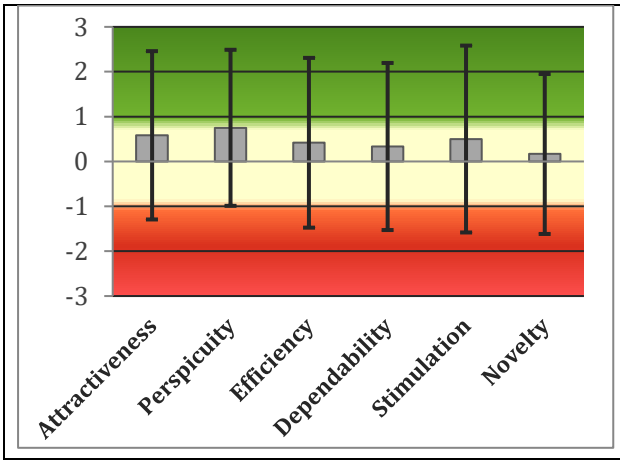

Figure 116: UEQ results for individual scales (Dynamic lists and sorting algorithms)

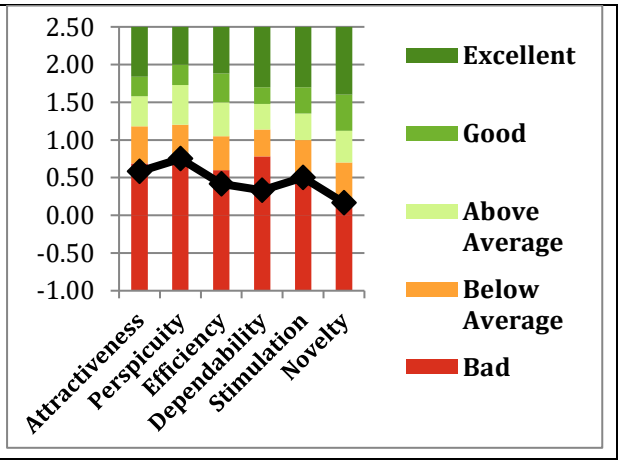

Figure 117: A benchmark comparison of UEQ results (Dynamic lists and sorting algorithms)

4.3.3 Simulator sickness questionnaire score

The SSQ evaluation shown in Figure 118 and Table 10 indicate that participants experienced nausea, evaluators had trouble with oculomotor discomfort and there was a very high level of feeling of disorientation. These results are inconsistent with the free questions asked in the end, where only one evaluator mentioned feeling slight dizziness. The scores are worrying as these results point to an unpleasant VR experience with a lot of VR sickness side effects and the SSQ-T is way above the 20 "bad simulator" threshold, likely due to a very small number of results making each low score influence the whole scale more than it would if there were more evaluators and results.

SSQ Scales (Mean and Variance)		
Scale	Average	SD
SSQ-N	20.443	25.497
SSQ-O	22.740	20.527
SSQ-D	53.691	51.728
SSQ-T	33.660	32.747

Table 10: SSQ results and variance for the Dynamic lists and sorting algorithms application

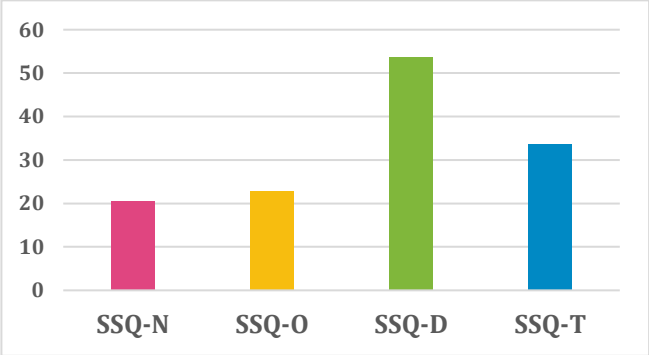

Figure 118: SSQ results for the "Dynamic lists and sorting algorithms" application

4.3.4 General comments and free evaluation feedback

The general impressions and comments from the evaluating participants were positive and most found it inventive, and novel mentioning that it creates a good concept with clear and understandable explanations. One participant mentioned feeling dizzy and another said the organization was not that great, while one wished for a better visual quality. Despite these comments all of them found the VR simulation better than traditional training with more engaging and higher efficiency of learning. They would all use the simulation again; this is interesting as the results of the UEQ were quite bad and these answers contradict those scores. The evaluators suggested increasing the graphic quality of the VR simulation and one proposed more customization options for the application that would make it more user friendly.

The overall response and review of the "Electromagnetic field" application was positive, offering users a more involved and innovative VR user experience, but the UEQ and SSQ results are worrying and need to be addressed as they paint a completely different picture of the VR application. The application should be reevaluated by a larger sample of test participants.

4.4 Course: Multimedia Communications

University of Prishtina's fourth VR solution "VR Equipment" application was developed during a master's level course Multimedia Communications. It had 6 evaluators that participated in providing feedback for the use of this VR solution. In the following chapter we will present the demographic profile, digital literacy, UEQ and SSQ results of their evaluation.

4.4.1 Information about participants

The first two figures represent the age and gender distribution of the evaluators. As seen in Figure 119 all participants were between 18 and 23 years old. The gender distribution between the evaluators favored males as they represent 67% with females only making up 33% of the participants, as seen in Figure 120.

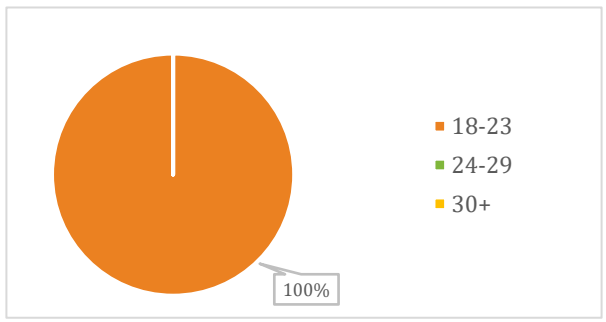

Figure 119: Participants' age distribution

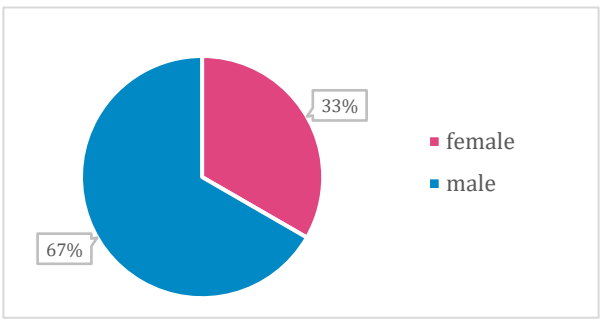

Figure 120: Participants' gender distribution

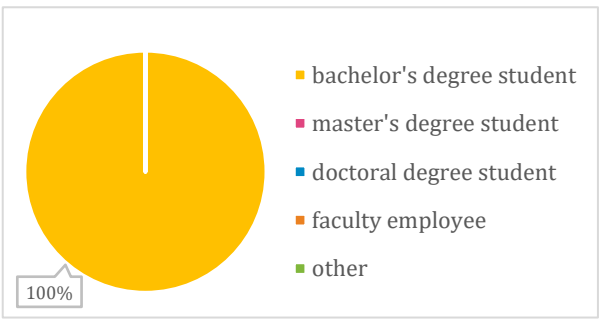

Figure 121: Participants' education and employment

Figure 121 shows that this group was completely made up of bachelor's degree students.

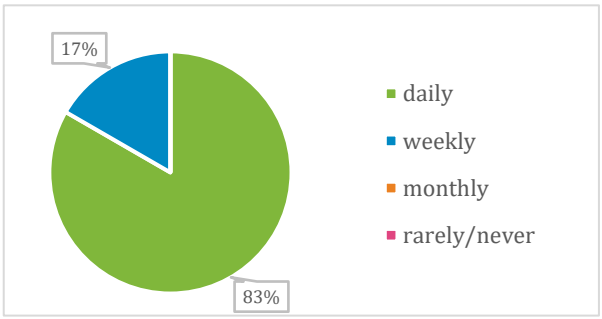

Figure 122: Participant's computer use

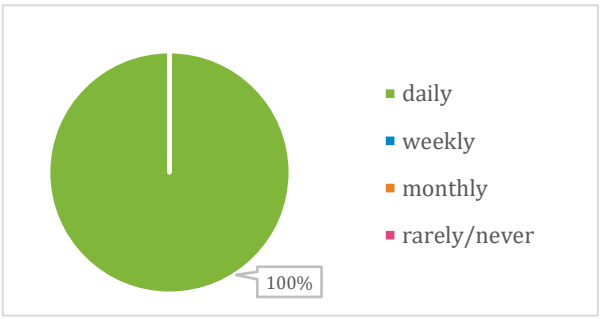

Figure 123: Participants' smart phone use

Figure 122 shows that 83% of evaluators use their computer daily and the rest weekly. All participants as seen in Figure 123 use smart phones every day.

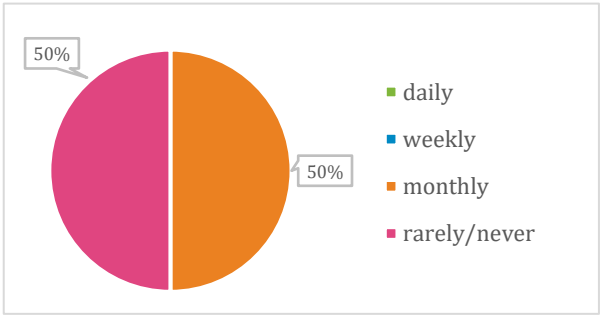

Figure 124: Participants' VR devices use (frequency)

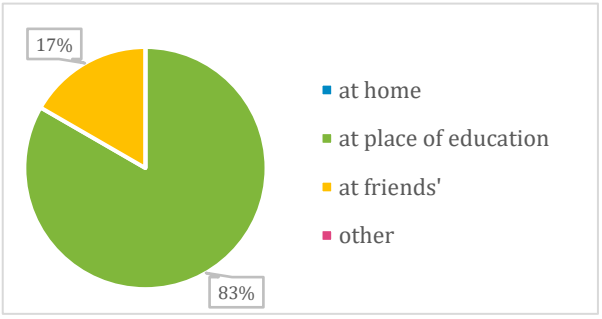

Figure 125: Participants' VR devices use (location)

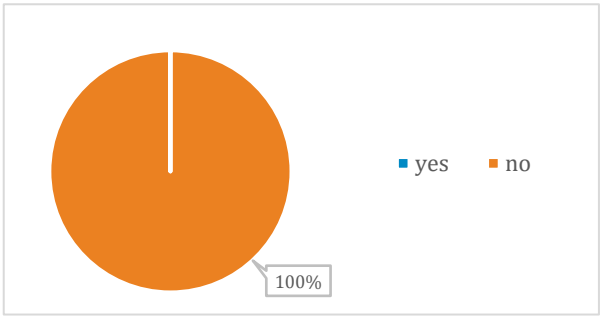

Figure 126: Previous VR sickness experience

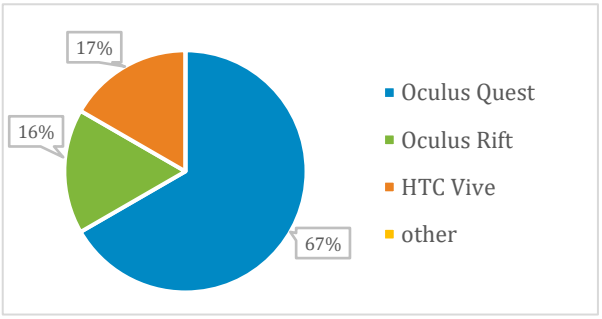

Figure 127: Share of used VR headsets during the experiment

The participants are split half and half into a group that has rarely or never used VR and those that use it monthly shown in Figure 124. The vast majority (83%) used VR at place of education with the remainder using them at friends' places as is seen in Figure 125. Figure

126 shows that none of the evaluators have ever experienced VR sickness side effects before. The main VR headset used was Oculus Quest (67%) followed by HTC Vive with 17% and a similar number of Oculus Rift with 16%, shown in Figure 127.

4.4.2 User experience questionnaire results

The UEQ results, presented in Figure 128 show that the tested application VR Equipment was received very well by all participants. All scales reached high results. The highest score was for stimulation with a 2.9 with the lowest being dependability with a still "excellent" 2.15. With these results the scores of hedonic quality and attractiveness were both 2.8, and pragmatic quality of 2.32. Compared to other evaluated solutions seen in Figure 129 all of the confidence intervals are excellent. Overall, the application was extremely well received. We might get some differing results if a study was done with a larger number of evaluators with more diverse experiences. With the current results the application provides an excellent VR experience.

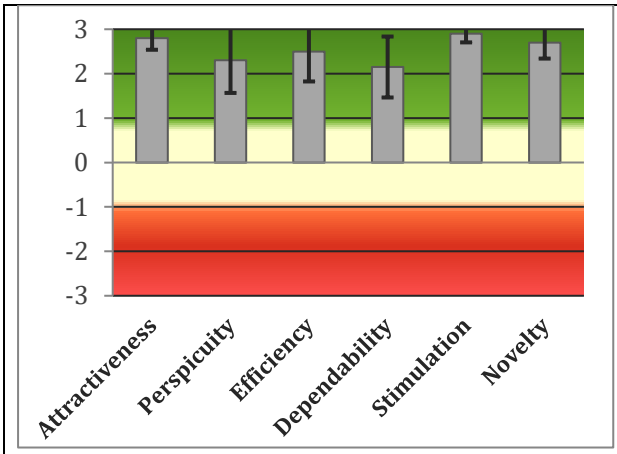

Figure 128: UEQ results for individual scales (Dynamic lists and sorting algorithms)

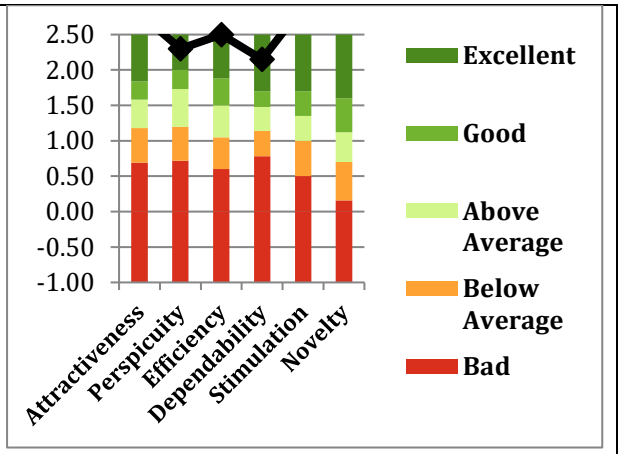

Figure 129: A benchmark comparison of UEQ results (Dynamic lists and sorting algorithms)

4.4.3 Simulator sickness questionnaire score

The SSQ evaluation seen in Figure 130 and Table 11 shows interesting results as the average scores are all high. Mainly for disorientation that reached really high numbers, oculomotor discomfort and nausea played a similar role. The results are interesting because the previous user experience scores were so high and in the free questions the participants do not mention any VR sickness side effects. The overall use of the VR solution might cause some discomfort and disorientation problems and the SSQ-T score is high.

SSQ Scales (Mean and Variance)		
Scale	Average	SD
SSQ-N	25.440	36.034
SSQ-O	29.057	36.953
SSQ-D	55.680	77.753
SSQ-T	39.270	52.400

Table 11: SSQ results and variance for the Dynamic lists and sorting algorithms application

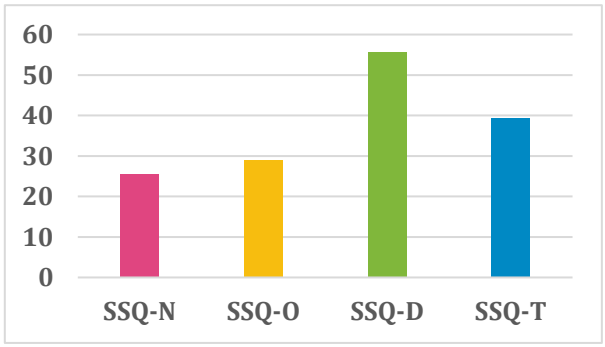

Figure 130: SSQ results for the "Dynamic lists and sorting algorithms" application

4.4.4 General comments and free evaluation feedback

The general impressions and comments from the evaluating participants were very positive stating that they found it detailed and interesting. There are no real negative feedbacks other than one participant disliking learning about VR' effects on the body. All except for one participant would use the VR solution again. When compared to traditional training they mentioned it was more advanced and interesting to learn. They mention the problem of this kind of technology not being accessible to many students in their country. There were no real suggestions for improvements of the solution from the evaluators, one wished they could see more used of VR at their faculty like VR graduation.

The overall response and review of the "VR Equipment" application was very positive, it offers a simple and understandable way of learning but the results of the SSQ might show a slightly worrying VR user experience from the side effects of VR sickness.

4.5 Bio-medicinal electronics

The last of University of Prishtina's courses, Bio-medical Electronics on master's level, had 6 participants that helped in the evaluations for the "COVID - 19 Detection" application. In the following chapter we will present demographic profile, digital literacy, UEQ and SSQ results.

4.5.1 Information about participants

The first two figures represent the age and gender distribution of the participants. In Figure 131 we see the majority of our participants were aged between 24 and 29 and the rest share similar percentages with 17% aged over 30 and 16% between 18 and 23. Half of the evaluators were women and the other half male as shown in Figure 132.

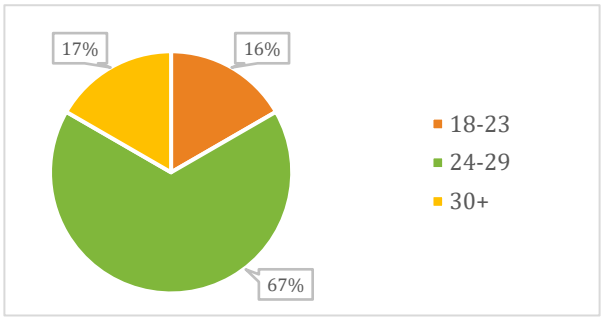

Figure 131: Participants' age distribution

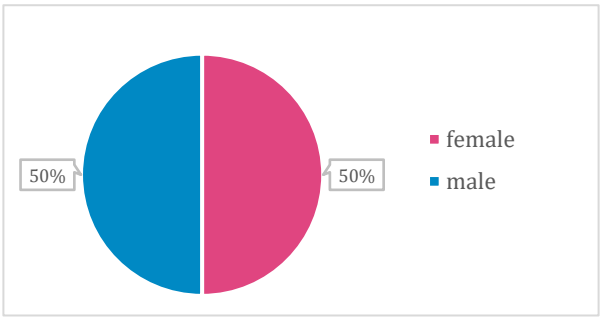

Figure 132: Participants' gender distribution

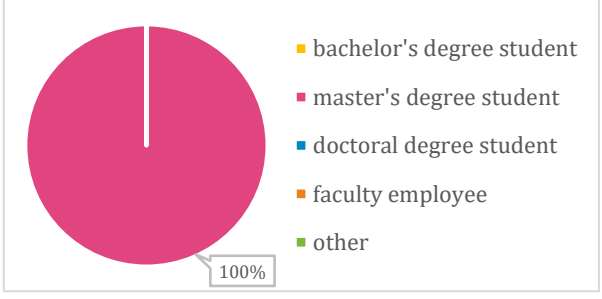

Figure 133: Participants' education and employment

Results in Figure 133 show that all participants were master's degree students.

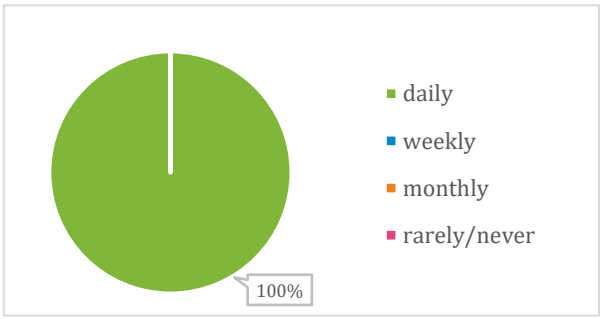

Figure 134: Participant's computer use

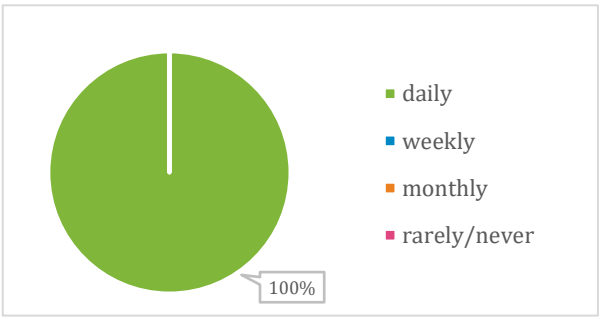

Figure 135: Participants' smart phone use

Results on Figure **134** Figure 135 are the same as all participants use both their smart phones and computers every day.

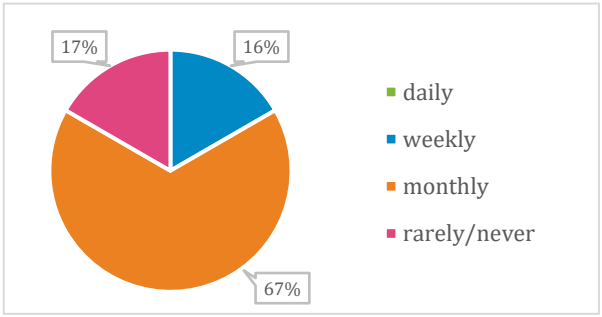

Figure 136: Participants' VR devices use (frequency)

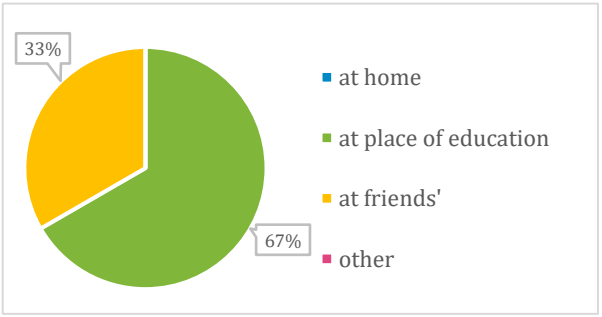

Figure 137: Participants' VR devices use (location)

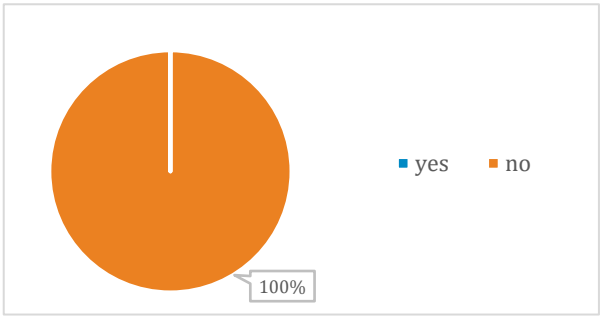

Figure 138: Previous VR sickness experience

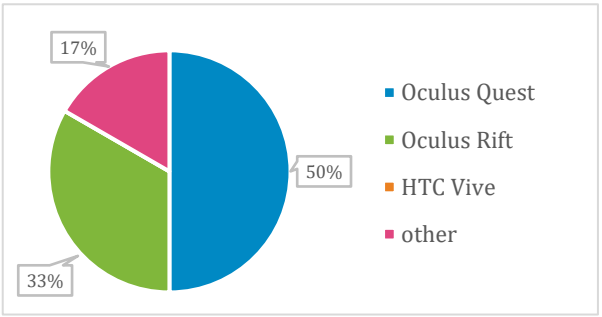

Figure 139: Share of used VR headsets during the experiment

The most frequent location where participants used VR devices' shown in Figure 137 is the educational institution (67%) followed by 33% that used VR at friends' places. As none of the participants have a VR device at home results in Figure 136 are interesting as only 17%

have rarely or never used a VR device, a majority (67%) use them monthly and 16% even weekly. Results shown in Figure 138 show that none of the evaluators ever experienced VR sickness side effects. Half of the participants used the same VR device, Oculus Quest, while 33% used Oculus Rift and 17% used other VR devices, see Figure 139.

4.5.2 User experience questionnaire results

The UEQ results, presented in Figure 140 how, that the COVID - 19 Detection application was well accepted by the participating users. The results across 4 scales show high values, while perspicuity and novelty are lower in comparison. The highest score was for attractiveness with 2.17 while pragmatic scales (perspicuity, efficiency and dependability) reached a score of 1.75 and the Hedonic scales (Stimulation and originality) reached a slightly lower score of 1.53. When compared to the database of other evaluated solutions seen in Figure 141 the confidence intervals are “excellent” on 4 of the scales and novelty reaches “above average” results, the only outlier is perspicuity with “below average” results. We can conclude that this solution is good in its design as well as in its implementation, but it could be more intuitive wasn’t so new and impressive to the evaluators.

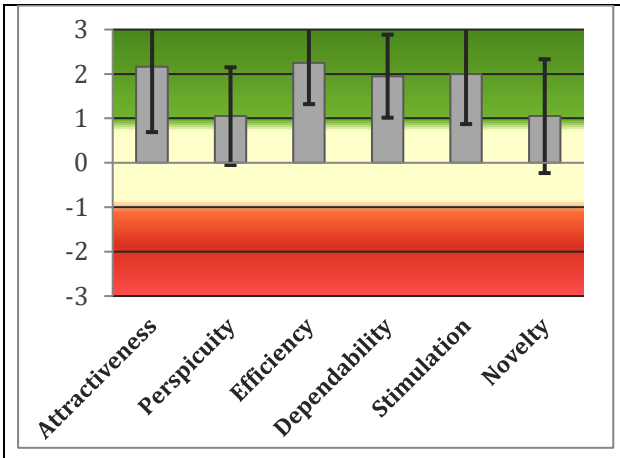

Figure 140: UEQ results for individual scales (Dynamic lists and sorting algorithms)

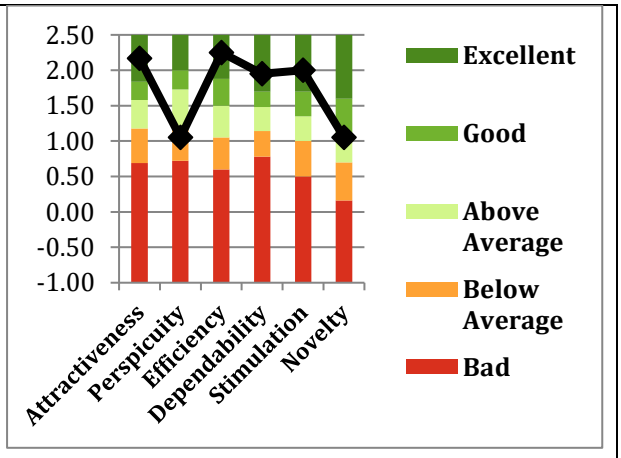

Figure 141: A benchmark comparison of UEQ results (Dynamic lists and sorting algorithms)

4.5.3 Simulator sickness questionnaire score

The SSQ evaluation has given some worrying results as the average values seem to be quite high, causing noticeable discomfort while using the VR application. This is especially true for the feeling of disorientation and oculomotor discomfort even nausea seemed to have caused an impact. This contradicts the results of the free questions, where only one participant mentioned light dizziness as a VR sickness side effect. Results are represented in Table 12 and Figure 142. We can see the SSQ-T score is high and it can be concerning if users actually experienced such high side effects.

SSQ Scales (Mean and Variance)		
Scale	Average	SD
SSQ-N	31.800	31.736
SSQ-O	41.690	41.448
SSQ-D	55.680	57.055
SSQ-T	47.997	46.797

Table 12: SSQ results and variance for the Dynamic lists and sorting algorithms application

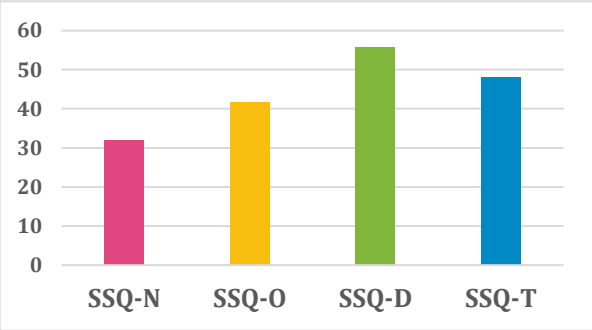

Figure 142: SSQ results for the "Dynamic lists and sorting algorithms" application

4.5.4 General comments and free evaluation feedback

The general impressions and comments from the evaluating participants were positive and they enjoyed the innovative and unconventional ways of watching and exploring a phenomenon in a virtual way. There was not enough information and instructions on how to use the solution according to some of the evaluators, while others had no negative feedback. When compared to usual ways of learning they all enjoyed the experience and would use it again in the future. They found it easier to understand and more practical. There were suggestions from some evaluators to improve on the solution making it more flexible, with better resolution with more variation.

Overall, the “COVID - 19 Detection” application was positively received, and it provides a fun and innovative way to view data but it needs improvements to make the user experience better and cause less VR sickness side effects.

5 Other VR applications

Three other partner Universities have developed VR solutions intended for their bachelor and master courses.

In the scope of the project POLIS University development team produced 3 VR solutions in separated courses.

1. Computational Aided Design integrated masters' course with the Immersive Architectural Design through VR Tools application that had one evaluator.
2. Computer Based Arts bachelors level course with Digital Design and Art through VR Tools application for which we didn't receive the collected data.
3. Interactive Design master's course with Interactive Digital Storytelling application that only had two evaluators.

The results from the project submitted by the European University of Tirana include 3 VR solutions in separated courses:

1. Anatomy course at bachelors' level.
2. Digital Design – Digital Visual Effects at masters' level.
3. Multimedia Communications at bachelors' level.

Finally, the UBT has reported 10 VR solutions in separated courses.

The results of evaluations for these courses cannot yet be presented as there were two or less evaluations done for each these courses. Therefore, the results would be very inconclusive and cannot be interpreted in a reliable manner.

6 Conclusion

In the scope of the Erasmus+ Vtech project more than 30 virtual reality applications and solutions were developed in the scope of bachelor and master studies at partner Universities. The general impression, obtained through evaluation of 18 of these applications, is undoubtedly a positive one. Almost every single one of the developed VR applications is reported as a positive contribution to the course study material, and an aid to better understanding of course contents. Consequently, most of them have reached very high UEQ scores across all scales, with one exception, which is probably a result of poor understanding of the UEQ questionnaire, combined with a low number of participants. Overall, the user experience of these applications seems to be very good, with minor improvements suggested in some cases. The results of the SSQ questionnaire are also within expectations, namely, most of the solutions do seem to induce a certain amount of simulation sickness, with most of the negative effects being related to disorientation. These negative effects are well known in the domain of virtual reality and can be reduced to a certain extent but cannot be eliminated completely. The general remarks of evaluating participants were very positive and encouraging with some recommending additional improvements or changes to the existing design, but overall praising the developed solutions.

Therefore, we can conclude that the developed VR solutions will benefit the courses at partner Universities and that usage of this technology is very welcome and beneficial to the study process. Inclusion of such solutions into the study process should be further encouraged and supported in order to improve the educational process in participating HEIs.

7 Useful links:

User Experience Questionnaire: https://www.ueq-online.org/

System Usability Scale: https://www.usability.gov/how-to-and-tools/methods/system-usability-scale.html

Simulator sickness questionnaire:
https://www.sciencedirect.com/science/article/abs/pii/S0003687019301759