

Virtual Reality For Training: A Computer Assembly Application

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Abstract—Virtual reality applications aimed at worker training to train professionals are more common with the virtual reality advancements observed in this day and age. More companies search for ways to improve the efficiency and efficacy of their training programs, whilst also reducing training costs. There are several training applications found in the literature, but not many focus on the theme of computer assembly, and only a few have options like an observer’s menu or a scoring system. With that in mind, a training application for assembling computer towers was designed. This article will focus on the application’s functionalities, the results of questionnaires made to evaluate its quality and usability and potential future work. The study realized had good results and a good, varied sample of volunteers, with a score of 93.4% in the custom-made questionnaire, a cybersickness (SSQ) score of 26.53%, a usability score (SUS) of 90% and a satisfaction (ASQ) score of 17.67%, being that a higher score is better in custom made and SUS questionnaires, and a lower score is better in the SSQ and ASQ questionnaires. Although this project is just a proof of concept, it focuses on a theme that will certainly be explored soon, with the rise of demand for training applications, the ever-growing “gamer” market, and workstations for the design of virtual reality applications, like the one described on this paper.

Index Terms—virtual reality, training application, usability evaluation.

I. INTRODUCTION

Currently, virtual reality (VR) has reached a point where the general public can access head-mounted displays (HMD) at low-cost, and without compromising the quality of these devices [8]. The number of available VR applications (app(s)) has also spiked dramatically, like in the game industry [6][7], professional sector, like virtual meetings, or the app type that shall be discussed in this document, virtual training apps. This type of application is proving important and useful in a wide range of businesses, due to the cost reduction in worker training, because the need to stop production lines ceases to exist, the HMDs and computers necessary for this training are much cheaper than halting production lines every time training must occur. This solution also helps reduce training time, component waste, and work accidents [1][9].

As a project to develop a solution directed at the computer assembly market, where not many solutions of this type exist, a prototype was developed. With it, new employees in need of

training, beginners in the area that may want to assemble their computers or even just learn how to, may learn the components of a desktop computer and the basis of how to assemble one.

II. STATE OF ART

VR training apps exist in variety in the market, although for this particular situation, not many were observed, so a wider search was conducted to find items that may prove useful in this situation.

The German-Spanish company Siemens-Gamessa [2], chose to improve the training efficiency of its collaborators in specialized, high-cost facilities of wind power generation, by attempting a VR solution (Fig. 1). The app serves to provide training in procedures and help in environmental habituation. It allows several users at the same time, with no time limits and permitting user blunder, but, at the same time, helps with visual assistance to help correct said flaws.



Fig. 1. Several training situations in the Siemens-Gamessa App (adapted from Radhakrishnan et al. [2])

An app designed by Opel, Virtual Assembly Line Training [3] is a customized car assembly line simulator (Fig. 2). This app helps to reduce up to 50% of the critical errors in training and assembly costs, and 40% reduction in operator training time. It also permits customization of the cars in the line, different workstations, and alteration of other details. Each operator has custom content tailored for their post. This app is not exclusive to VR, as it is compatible with a mouse and keyboard or an Xbox Kinect.

PC Builder Hero [4] is a VR computer building experience where a user (one at a time) can assemble a computer from



Fig. 2. An example of usage of the Virtual Assembly Line Training App (adapted from [3])

start to finish (Fig. 3), and at the end know the price of the current build of the computer. Whilst being minimalistic, it demonstrates the basic steps in computer assembly, component cost and even proper component handling, as static charge can harm electronic devices. This application is intended for personal use, to teach the inner workings of said computer without the danger of costly mistakes. Although this application is a prototype, it presents very similar features to the ones designed for large enterprises.



Fig. 3. At the right we can see the parts available to assemble the computer, along with their prices, at the left we can observe the computer being assembled and the current cost of the build in PC Builder Hero (adapted from Slovikosky et al. [4])

A company by the name of The Irregular Corporation [13], developed an app by the name of PC Builder Simulator, mostly as a game and not for training, that allows the user to run a computer shop where you assemble and repair computers, or it is possible to create computers using every component available in the game. It allows for several different component configurations, as well as software tinkering and even goes as far as having malfunction troubleshooting. However, this application is mostly for personal use and does not currently support virtual reality.



Fig. 4. View of a test bench in Pc Builder Simulator (adapted from [13])

This application presented in fig. 5 (adapted from He et al. [6]) belonging to the industry of construction equipment, is not associated with any company, nor does it have a name. The necessity to increment production rate and quality, and reduce training time and component waste, this VR solution proves beneficial in a sector that is slowly switching over to more precise, digital equipment. A study conducted to test this application gave it a very favourable result.

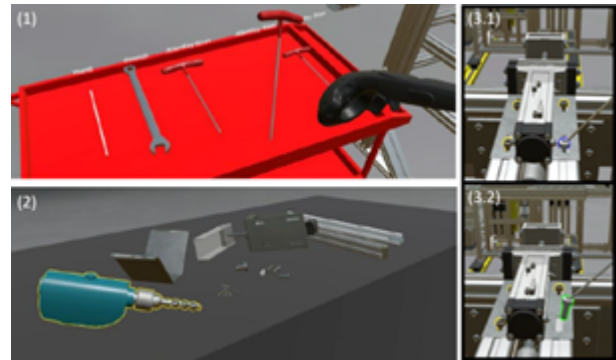


Fig. 5. In (1) we can observe several types of available tools in the VR environment, in (2) a set of parts before assembly, and at (3.1) and (3.2) we can see visual cues that help identify the next steps of the user (adapted from Barkokevas et al. [5])

These apps may be associated with different areas of expertise, but they all share the training theme. However, there are many details that differentiate them function wise. All of them except for PC Building Simulator function in VR, have a wide array of available interactions, and have visual cues to assist in the procedures. Every app presents faithful simulations, help reduce procedural errors, reduce training time, diminish work accidents and component squander. In the case of the Siemens-Gamessa app and PC Builder Simulator, it allows for user error and helps correct those errors. PC Builder Simulator and Virtual Assembly Line Training allow for scenario customization. However, none of these apps present a timer function, none of them have a scoring system able to accurately measure the trainee's performance, and Construction Equipment Assembly Training has its immersion affected by utilizing controllers instead of virtual hands in its simulation.

III. APPLICATION DEVELOPMENT

With the goal of creating a software capable of helping reduce employee formation times, product waste reduction, and at the same time, contributing to an enrichment in the formation techniques, and dwelling in an ever-growing theme that is gaming computers and the companies that assemble these.

To be able to create an immersive app, a VR approach was used, where, in a training scenario, similar to a computer shop, the user can experience the same steps of assembly as they would be in the real world, with the addition of visual cues to help the user better understand what he has to do, and a simple scoring system, to promote better performance of the user after a few tries. As a component not necessarily important in an

app of this type, but to instigate a better feeling of presence of the user in the scenario, outside stimuli like wind and heat were used.

The heat and wind components were generated with an Arduino, with a circuit created to connect the fan and infrared light bulb, and a simple code set to run them, with a serial output directly from Unity.

IV. REQUIREMENT ANALYSIS

The prototype so far only allows the training to be achieved in a sequential manner, with every component present but only used when the application calls for it. The requirements that were set for a successful app were:

- The app must have a realistic representation of the work environment;
- The app must cover all steps of the computer assembly;
- The app's assembly steps must be accurate and similar to reality;
- The app must have an observer point-of-view (POV), where an outsider may observe, guide, or grade a worker's performance;
- The app must have a scoring system;
- The app must record the worker's score;
- The app must have a timer;
- The app must record the worker's completion time;
- The app must allow teleportation movement.

The non-functional requirements are:

- The app must have interactions easy to understand;
- The app must have interactions easy to use;
- The app must have accurate interactions to when compared to reality;
- The app must be developed in Unity (VR);
- The app must be developed for the Oculus Quest/ Quest 2 system.

Although other head-mounted displays may function correctly with the app, it was developed and tested with the Quest (1 and 2), connected to a computer.

V. REQUIREMENT ANALYSIS

A prototype was developed based on the Oculus system, more specifically, the Oculus Quest (1 and 2) HMD, connected to a computer via Oculus Link.

In Fig. 6 we can observe a complete view of the training scenario, with an "ideal" look of what the inside of a computer store's workshop would look like to the developer. The spotlights in the scenario are a way to direct light to the computer being assembled, to have a well-illuminated workspace.

In Fig. 7 we can observe some of the parts of the computer, where the object to be picked up and its destination are highlighted, and the components are named. This happens in sequence in all the parts and actions of the computer and serves to help guide what he is meant to do next.

In Fig. 6, as well as in Fig. 8, there is also a monitor that attempts to guide the user in what part he must assemble next. Step 3 is where the user will test the function of a fan, and



Fig. 6. A complete view of the scenario developed.



Fig. 7. A component of the computer is highlighted, as well as its destination. The components are also accompanied by their names.

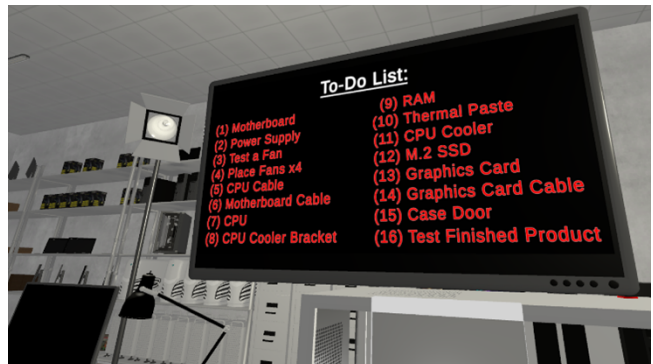


Fig. 8. A monitor displaying the computer's assembly steps.

after pressing the button he will feel a gust of wind, as he would in a real-world scenario. In step 16 the user clicks the computer's power button, causing it to "spin" 180° and, with the fan turned against the user, spew a few seconds of warm air, produced in the real-world, and felt in the virtual one. After this, the computer finishes "booting up" and the user's score is displayed (Fig. 9).



Fig. 9. A completed computer and the user's score.

Fig. 10 shows the observer's point of view, and if the computer has a second screen, a dedicated HMD POV is displayed there. It has options for four different camera positions and a first-person option for cases where there is no second screen to observe the player's POV.



Fig. 10. Observer's Menu, with different Points of view, time, and player position.

The existing scoring system is quite simple with three possible evaluations depending on assembly time. Under two minutes is "Good", from two to ten minutes it is "Average" and over ten minutes it constitutes "Slow". This scoring was created subjectively and is merely indicative, but still, attempts to inspire the user to do better.

The interactions are basic, to simplify the user's experience, basically revolving around grab and drop operations (Fig. 11). A teleportation system is fully functional, and the action area is limited to the blue patch (Fig. 6) in the ground. There is also a free movement option, where the user can move around with the analogic input of the left remote but needs to be activated with a button in the right hand, as it is cybersickness-inducing for most users.

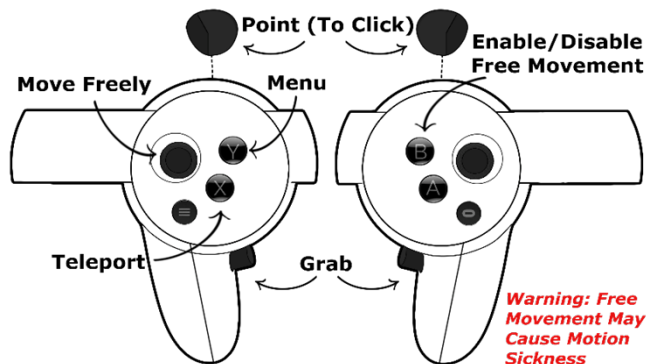


Fig. 11. Oculus Quest 2 Controller Scheme for the prototype (created by the authors).

VI. APPLICATION EVALUATION

A. Sample

To evaluate the usability and quality of the prototype, a between-subjects study was conducted with the participation of 23 volunteers from different age groups (14 to 53 years old, with an average age of 30 years old) and different work areas and education paths, with fourteen participants having at least an academic bachelor, two high school students, six people with completed high school, and one volunteer with only middle school level of education. Eleven of these volunteers had an academic bachelor in Informatics Engineering, two of which are already employed. The study sample had twelve students, ten employed individuals and one unemployed person, meaning the study used a diverse and disperse sample of volunteers.

B. Materials

The experiment was conducted using an Oculus Quest 2 HMD, a custom-made Fan, Infrared Bulb, Arduino controlled stimuli system, and a laptop computer with 16GB of ram, a i7-10750h CPU, and a 3080m GPU. The app ran from the computer into the Quest 2 Headset via cable connection using the Oculus Link functionality.

C. Instruments

The instruments of evaluation used were compiled into a single Questionnaire, consisting of a general questionnaire for demographical analysis, a custom-made questionnaire for this application and three validated questionnaires, the Simulator Sickness Questionnaire (SSQ) [10], the System Usability Scale (SUS) [11] and the After-Scenario Questionnaire (ASQ) [12].

D. Procedures

Each volunteer was sat on a chair in front of the stimuli device, given a briefing of the controls, and then equipped with the HMD. During the experiment, and using the observer's menu, the volunteer was assister throughout the experiment. When the experiment was complete, the evaluator took note of the score and time of the volunteer, and the volunteer was given a questionnaire to fill out.

TABLE I
TABLE TYPE STYLES

Variables	Minimum ^a	Average	Maximum ^a	% Obtained
Age	14	30	53	/
Experience With Computers	None (1)	Intermediate (3.26)	Good (4)	81.5%
Experience With VR	None (1)	Basic (1.96)	Good (4)	49%
Time	2 minutes & 43 seconds	4 minutes & 57 seconds	9 minutes & 10 seconds	/
Score	(Score: Average)	(Score: Average)	(Score: Average)	/
Custom Questionnaire Score	161	752	805	93.4%
SSQ Score	812.63	862.2	3250.51	26.53%
SUS Score	0	90	100	90%
ASQ Score	69	86	483	17.6%

^aIn the Age and Time/Score fields, the minimum and maximum are the lowest and highest values attained, respectively, whilst in the other fields it states the minimum and maximum possible values attainable.

E. Results

In the sociodemographic questionnaire we could observe a mix of users with low, medium, and high experience in computer interaction, and even though some users had previous experiences with VR, more than half did not. Still in this questionnaire, the score for each user was retrieved, and all users managed to stay in the Average score (Good is under two minutes, Average is between two and ten minutes, and Slow is over ten minutes), with an average completion time of 4 minutes and 57 seconds, which is particularly good for a first interaction with the app. It is worth noting that this scoring method is purely subjective and of the authors' opinion, given the complexity of the actions asked, and made in order to understand if the user is improving with successive attempts, something that this study was unable to evaluate.

The first questionnaire, with questions better aimed at this application, in particular, has seven items, which attempt to find out if the app was immersive, if the external stimuli were effective, if the environment had good quality and if the user learnt anything useful with the experiment. The heat component was less effective in some of the tests, due to the elevated temperature of the testing room and the necessity of the stimuli apparatus to be at a certain distance from the user, so that the user would not hit the device. This questionnaire had a scale from one to five (totally disagree and totally agree, respectfully), with a minimum score of 7 and a max of 35 (in this case, the more points the better). Some of the questions had a negative connotation, and so their points were reversed. The max possible score was 805, and the score archived was 752, with an average of 32.7 points per user, leading to a good score of 93.4%.

The second questionnaire, the SSQ [10], in which the user must answer which symptoms out of sixteen he felt after the experiment, from one to four (1 is none, 2 is slight, 3 is moderate and 4 is severe) and the fewer points achieved the better the app is. This questionnaire has a complicated scoring system, as shown in Fig. 12, and so the minimum score per questionnaire was of 812.63 and the max of 3250.51, with nausea average of 68.4 points, and an oculomotor average of 58.0 points, a disorientation average of 104.1 points and a cybersickness average of 862.2, meaning that most users did

not feel any aftereffects of the experiment, with a total score of 26.53%. The most signalled option of all the questionnaires was ocular fatigue, which was most likely caused by the fact that the HMD used in the experience did not possess enough clearance for most glasses.

Symptoms	Weights for Symptoms		
	Nausea	Oculomotor	Disorientation
General discomfort	1	1	
Fatigue		1	
Headache		1	
Eye strain		1	
Difficulty focusing		1	1
Increased salivation	1		
Sweating	1		
Nausea	1		1
Difficulty concentrating	1	1	
Fullness of head			1
Blurred vision		1	1
Dizzy (eyes open)			1
Dizzy (eyes closed)			1
Vertigo			1
Stomach awareness	1		
Burping	1		
Total*	[1]	[2]	[3]
Score			
Nausea = [1] × 9.54			
Oculomotor = [2] × 7.58			
Disorientation = [3] × 13.92			
Total Score = ([1] + [2] + [3]) × 3.74			

* Total is the sum obtained by adding the symptoms scores. Omitted scores are zero

Fig. 12. The calculations in the SSQ Questionnaire.

In the third questionnaire, the SUS [11], for evaluation of the usability of the app, is composed of ten items scored from one to five (totally disagree and totally agree, respectfully), where the ideal score of 100 points, and a minimum of 0 points. Of the twenty-three participants, twenty graded the app as "Excellent" and only 3 as "Good", with an average usability score of 90, which translates to an excellent app, a great score in the evaluation diagram of the SUS questionnaire (Fig. 13) sets the app in between the excellent and ideal scores, with very acceptable usability and within the fourth quartile range.

The fourth questionnaire, the ASQ [12], measures the satisfaction of the users with three questions, graded from one to seven (totally agree to totally disagree, respectfully),

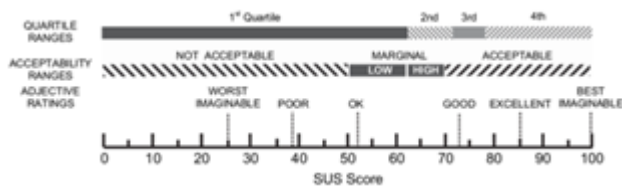


Fig. 13. The calculations in the SUS Questionnaire.

in which the least points, the better the satisfaction is. Out of a minimum of 69 points and a maximum of 483 in the twenty-three questionnaires, the result was a score of 86 points, with an average of 3.7 points per questionnaire (Where the minimum is 3 and the maximum 21), resulting in 17.6%, meaning high satisfaction with the app. All of the resulting values were compiled into Table I.

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