A Comparative Study of Virtual Reality and Traditional Methods in Cryptocurrency Learning

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Abstract

For the past decade, cryptocurrencies have gained a lot of popularity and unfortunately are often misused by criminals. Law enforcement organizations are often behind the mainstream knowledge about cryptocurrencies which makes investigations and funds withdrawal from criminals less effective. This raises a need to educate law enforcement organizations about how cryptocurrencies work and how to recognize their usage. Traditional teaching methods, like manuals and slide presentations, show mixed results which prompted alternative approaches. This research paper aims to test whether a serious VR game that we developed provides higher learning outcomes in terms of learnability and willingness to learn in this way compared to a cryptocurrency checklist. The prototype was developed based on literature review, expert interviews and user testing. To measure the effectiveness of both cryptocurrency checklist and the serious VR game prototype in terms of knowledge of the cryptocurrencies, we designed a questionnaire. Results showed that participants scored slightly more after reading the checklist, though with no significant statistical difference, and found the VR game more enjoyable and engaging. The prior knowledge of cryptocurrencies had a significant positive impact on the results, outweighing the value of prior gaming experience and age. This study concludes that both learning methods have their own place and should be used together for optimal learning outcomes.

Keywords

Bitcoin, Cryptocurrencies, Game Development, Serious Games, User Experience, Virtual Reality.

Contents

List of Abbreviations

FIOD	English: Fiscal Information and Investigation Service Dutch: Fiscale inlichtingen- en opsporingsdienst
GBL	Game-Based Learning
IQR	Interquartile range
KMAR	English: Royal Marechaussee Dutch: Koninklijke Marechaussee
LBD	Learning By Doing
LTM	Long Term Memory
STM	Short Term Memory
UX	User Experience
VR	Virtual Reality

1. Introduction

In the age of digitalization and cybernatization, it was inevitable that a form of digital money would appear. According to recent research on coexistence of cryptocurrencies and fiat money, Bitcoin emerged which triggered a huge wave of public interest in cryptocurrencies [1]. As the author says, cryptocurrencies are not backed up by a central bank or any governmental authorities, unlike fiat currencies such as dollars or euros. Such a way of working allows us to ensure some degree of independence and anonymity, but it also can be abused by criminals [2]. Thus, law enforcement organizations must adapt to the new reality and be able to recognize and know how to use cryptocurrencies to prevent and combat their misuse.

That is why cryptocurrencies pose interest to FIOD (Fiscal Information and Investigation Service) - a Dutch government agency for combating financial crime, tax evasion, money laundering and other financial offences. In the Netherlands, specifically at FIOD, the detection of cryptocurrencies is relatively underexposed within criminal investigations [3]. The author says that the purpose of the cryptocurrency checklist to be created was to avoid, unknowingly, leaving seizable assets behind. However, the author of the checklist found that the checklist together with presentations and verbal explanations have a limited learning effect on his colleagues. The information is often forgotten and mixed up. Because of that, FIOD found a possible alternative or addition to presentations and checklist which is a serious VR game.

Serious VR games seemed like an attractive solution because they supposedly provide better immersion and engagement in the process, more fun and clearer than traditional learning methods. This all together formed an assumption that serious VR games may be more effective for FIOD employees to learn to detect usage of cryptocurrencies than the checklist and presentations. The goal of FIOD was to find out how useful serious VR games could be, but it was not the goal to replace the “old” methods of education but rather to combine them if the assumption about the serious VR games is at least plausible. Such an approach is justified by a study about Learning By Doing (LBD) principle [4]. The author argues that LBD effect alone is quite limited and must be combined with strategic innovation and development efforts. The results of this study, in addition to helping FIOD itself in criminal investigations regarding cryptocurrencies, may impact the future use of serious VR games not only in FIOD but also by their business partners from law enforcement and governmental organizations, in a perspective – creating a bigger demand on VR technology making it more accessible in a long-term.

2. Methods

1.1. Literature study

Literature study was conducted to obtain information on existing research documents on serious (VR) games, and their effect in learning for individuals.

Since we strive to achieve a noticeable learning effect with the VR prototype, we would like to know what triggers the best learning performance. The research by Charlotte Nickerson suggests that there is a clear relationship between stress and performance and that there is an optimal proportion of stress that gives the best learning outputs [5]. The research shows that the moderate stress level or arousal level is the best when it is moderate, while very high and very low levels of arousal lead to poor results. Such a relationship is called “The Yerkes-Dodsons Law” as the study suggests. Knowing such a correlation between stress and performance, the VR prototype needs to raise moderate level of arousal for the players. However, Gunther Baumler argues the efforts to replicate the experiment on the Yerkes-Dodsons Law led in the most cases to negative results [6]. In addition to the proper arousal level, Roberto Dillon states that it is crucial for serious games to be fun and engaging, even though the entertaining factor is not the primary goal of the gaming experience [7].

To maintain the proper level of arousal in the VR prototype, we thought of adding basic gamification elements such as timer, top score and leaderboard as we were unsure what effect it will have on the learning quality. The research we found demonstrated that with the timer, research participants had to take more turns to complete the level of a strategy game, where less turns – the better it is [8]. According to the research, with no timer, all metrics regarding players’ performance with top score and leaderboard were lower than with timer, meaning that they performed better. In addition, the study also showed that having both top score and leaderboard with no timer resulted in the best score possible. If either the top score or the leaderboard was removed or the timer was present, the performance was lower. Even though our research scope did not allow us to implement the top score and leaderboard mechanics, our research participants were curious about their own score as well as the score of others. For the future of the VR prototype, adding the top score and the leaderboard is recommended.

The study called “Game-Based Learning” indicates that people do learn from games and the quality of learning process depends on the game design [9]. While researchers say that they do not yet have generally effective techniques, processes and procedures for reliably achieving learning goals, they do share a game design recommendation. The researchers state that novice players waste a lot of time learning to navigate the game, which raises a need for proper instructional support in the form of guidance. The researchers say that it is more desirable to provide pictorial, rather than textual support.

Looking for a suitable visualizations for player controls in the in game-tutorial, we came across with one quasi-experimental study which aimed to improve the technical skills of young novice basketball players [10]. 20 players were equally divided into a control group and a video modelling group. The results of

the study show that the video modelling group demonstrated noticeably higher performance than the control group. The study gave us an idea to incorporate the in-game video tutorials.

Another study on tutorials discovered what kind of tutorials suit the best for explaining the control scheme for the VR controllers [11]. The researchers compared various methods and came to conclusions for each type of game. For puzzle games, which suit the best to describe our prototype, the researchers found out that *Text+Spatial* solution, when text with controller tooltips appear near or on top of players' virtual controllers, was the most appropriate.

The game tutorial level we aimed to build relied on learning by doing (LBD) principle. According to the researchers, LDB suggests that the more repetitions are done, the quicker the mastery is achieved, however passive repetition with no guidance will be insufficient [4]. To avoid the stagnation in learning gains and support the initial learning and long -term retention, the researchers suggest active engagements, visual clues and video modelling.

According to Sam Kavanagh and others, VR is used the most often by the researchers to increase the intrinsic motivation of students, and the most frequent solutions designed in VR have a goal to prepare people for specialized situations, for training purposes, while it is not clear enough if such an education method is suitable for non-specialized digital education [12]. Moreover, the research also points out the limitations of the VR solution related to high costs and maintenance of the VR devices. A lot of the research participants stated that the biggest problems they had with the VR solutions were software usability and insufficient realism.

The research done by Johan Ekmar from the Stockholm University states that despite the better accessibility of desktop videogames, VR provides higher levels of enjoyment and engagement mainly to noticeable level of immersion, naturalistic interactions and the body's freedom [13]. The researcher suggests not to ignore the risk of VR addiction. According to his findings, the usage of entertaining elements in learning may backfire, leading to the attention shift from studying to playing. These conclusions suggest that while VR is a powerful tool, relying solely on VR is not desirable, and the more optimal solution would be combining multiple ways of training.

One more research shows a successful application of the VR escape room in education [14]. The goal of the researchers was to create an immersive VR escape room to teach building energy simulation topics. According to this research the escape room level provided a visually appealing, engaging and usable environment by arousing players' curiosity. Another research also shows a substantial knowledge transfer when using the VR compared to slides [15]. The research participants of the same study also indicated VR experience as their preferred and more exciting learning tool than slides. In addition, the study illustrates that the research participants demonstrated significant knowledge retention, even after a week since the experiment.

1.2. Expert Interviews

To get more in-depth insights on applying VR games for learning, interviews were held with representatives of various business partners of FIOD, including Fontys University of Applied Sciences, BlueTea, KMAR and Police of Amsterdam.

Expert interviews were held with different goals depending on the current stage of the project.

The first interview was held with Mario Paiano - a teacher from Fontys University - to set up a basic understanding of the best practices for building VR applications. Mario suggested keeping the project idea reasonably small and quite practical, but not too creative because of the research scope. The level should consist of 3 or 4 rooms maximum. This will make sure that people who are not so experienced with VR will not get tired too fast. He also suggested drawing floor plans along with mood boards for better level design. Mario also stressed that it is highly recommended in VR to avoid text and more audial representation of what you would want to use text. For detailed meeting notes refer to Appendix I.

The second meeting, which was with BlueTea representatives, allowed us to ask more in-depth questions regarding serious games development and get a tool that makes further development of the prototype easier. The company is busy creating serious games for various clients. Some of the games that BlueTea has created: fire safety games, safety on a workspace game, surgery game, car industry game, interior design game. Most of the games mentioned are not made for VR. According to Dirk Bongers – CIO of BlueTea, usually the non-VR games are in bigger demand for the company than VR games. Usually, BlueTea recommends non-VR games for better accessibility, cost saving and ease of use, unless deep immersion with the environment is necessary and is a primary focus. On our question which game is better for learning purposes – a single player or a multiplayer game. Dirk Bongers suggested sticking with a single player solution as a multiplayer solution brings a lot of complexity in score, timing and synchronization management, as well as increases development and testing time. Additionally, we discussed the purchase of the tool that BlueTea is developing and using for their games – Virtual Studio. This tool allows access to some of the game logic, scenarios and behavior to the web browser client where people with less game development experience can review and contribute to the development. As a result, a decision to acquire this tool was made to integrate it for the further development of the prototype. For detailed meeting notes refer to Appendix II.

Another meeting was held at the KMAR simulation center. The goal was to see how they are using and developing their own prototypes, see what effect VR games have on their users, and to receive guidelines for making proper VR in-game tutorials. A useful insight that was shared with us was that KMAR did their own tests with recruits that involved using paper instructions and tests and serious VR games. According to KMAR more than 75% of recruits aged 17-21 liked and scored better with VR game experience than with the paper instructions. Around 20% suggested certain improvements for the VR experience while the rest, a small minority, did not like the VR experience when they tried it or did not try it at all. What KMAR does to explain user controls is dedicate a separate button on the VR controller that calls small hint panels that explain what each button does. Those hint panels relate to a line to the button they explain. Such a construction is not static – it moves together with the VR controllers and the

panels with text are located the way that it is always readable for players, no matter how they hold the controllers. According to the study, such a way of explaining controls leads to the highest control learnability, player experience, intrinsic motivation, and performance on average, which supports our findings from the literature study. KMAR also suggests that tutorials should explain only basic controls and interaction but not explain every single mechanic and interaction and let the players explore it themselves. For example, the item grabbing game mechanic should be explained to players, for example they can pick up a cup. But it is also possible to open the drawer in the game, and that is for players to explore. What is more, we explained to KMAR that we have a lack of 3D models to illustrate every cryptocurrency or other asset in the game and for that we must either buy such models or hire an artist. On that, KMAR offered us their help as they already possess a big library of 3D models, and they have their own 3D artists to draw any 3D model desired.

When significant progress to the VR prototype had been made, we scheduled a meeting with Mario Paiano again and his colleague Mark Mettsen. The goal was to review the existing version of a prototype, give us feedback and tips regarding player dizziness, ease of control.

1.3. Available Product Analysis

An analysis of the existing “Cryptocurrency Checklist” was carried out to understand how FIOD is currently educating employees to recognize cryptocurrencies, what information they are giving. This would serve as a base for future improvements on the base of a VR game and further comparison of these methods in learning efficiency.

The cryptocurrency checklist is a document that can be used by financial investigators to recognize the use of cryptocurrency by suspects at different stages of a criminal investigation. The document describes, with examples, the different items to look for during the investigation. The checklist focuses on two main stages of the investigation – the preliminary investigation and the action day search.

At the preliminary investigation phase, the document focuses attention on analyzing banking transactions, checking email and IP-tap. The same chapter lists examples with images of what are the different cryptocurrencies, mobile applications related to hot wallets and crypto platforms, desktop application icons, encrypted email providers and messengers.

For the search – action-day, the document provides examples with pictures of various hardware wallets (see Figure 1), mnemonics or seed phrases, QR codes and bank cards that need to be seized during the search. This section was particularly interesting to us, and we focused on building our VR prototype around this section of the checklist.

Figure 1: A page from cryptocurrency checklist

1.4. Development of assessment tools

Taking the research scope into account, there was a need to create a relatively simple way of comparing two learning methods. The decision was to create 2 questionnaires which consist of 3 sections. The first section asks about respondents' age, their estimated experience with cryptocurrencies and video games. The second section contains questions about cryptocurrencies and estimates knowledge of the topic. The third section asks about respondents' personal impressions and feedback. All respondents were divided into 2 groups. The first group read through the checklist with a questionnaire first and only then did they play a VR game with the same questionnaire. The second group first had VR experience and then the checklist. The questionnaire was created with considering the best practices for designing questionnaires from studies by Jon A. Krosnick [16] and Naresh K. Malhotra [17]. In total, 19 people participated in the research (N = 19), meaning that they both read the cryptocurrency checklist, played the VR game and answered the questionnaire. Each participant could score a maximum of 20 points per questionnaire regarding their knowledge of cryptocurrencies.

To ensure fair comparison between the cryptocurrency checklist and the VR game in terms of their efficiency regarding learning to recognize cryptocurrencies, the questionnaires that were soon created

consisted of questions that answers on which could be found in both products. For example, there is a question “Pick **all** devices that are specifically designed to securely store a recovery phrase” (see Figure 2). Both checklist and VR game have info about all crypto currencies and crypto coins that are considered correct in the questionnaire.

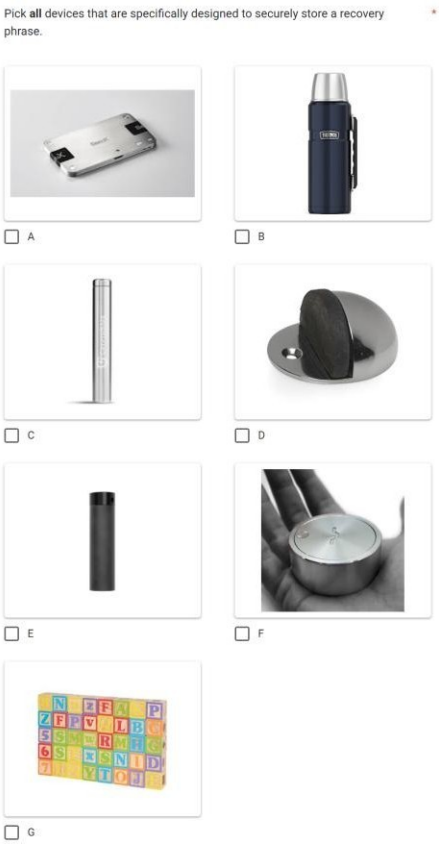

Figure 2 (Example of the questionnaire question)

1.5. Prototyping

To make a fair comparison between the efficiency of the checklist and a VR game, such a game must be created. Due to the nature of serious VR games, we decided to stick to some of the principles of participatory design framework. Every iteration of the game prototype was tested by people from the target audience, mainly by FIOD employees. Such feedback is crucial to ensure the optimal gaming and learning experience.

The first prototype was not even about learning to recognize crypto assets but more like a learning project to learn how to implement basic VR interactions in the game engine. Such a prototype would serve as an example for FIOD of what VR is capable of.

Next iteration was intended to take the environment where FIOD employees could conduct a search and make this environment interactive. Every door and drawer and most of the objects were made

interactive. This allowed us to make a mechanical base for the whole prototype. After all, that is what the game is about: explore the environment and find all crypto related assets. Unlike the first prototype, this iteration contained more complex interactions like opening doors and drawers. To make the process of opening doors and drawers realistic and immersive, more complex Unity physics had to be applied.

Another iteration involved creating an in-game tutorial which looks like a separate level. The level looks like a simple corridor with many sections. Every section contains one gameplay element to be learned. These sections are separated from each other with various types of doors. Almost every section has a video tutorial explaining what players should do to continue. Players could move to the next section only if they successfully applied the knowledge from the video tutorial and their own thinking process. At this stage, such mechanics were added like crouching, painting interaction, physical buttons, doors that can only be opened if the right key is inserted and table for gathering crypto assets.

Next iteration added a mini museum about crypto at the tutorial level, save with a passcode that consists of crypto elements, light switches, more game sound and test version of player inventory with certain bug fixes.

Every iteration we tried to ensure players did not get tired or nauseous very quickly. For that we experimented with types of movement, game performance and optimization.

1.6. Used tools

The VR game prototype was developed using Unity game engine and C# programming language. The project has integrations of Virtual Studio – a proprietary tool from BlueTea that makes the development and maintenance of the VR solution easier for people with less technical background. The test platform for the VR game was Meta Quest 3. Even though the game was tested exclusively for Meta Quest 3, it was built using Extended Reality Interaction Toolkit that ensures more cross platform and future proof compatibility than the Oculus toolkit.

1.7. Results interpretation

To understand the significance of the difference in game scores for both learning methods, we applied several unpaired t-tests. To find correlations between different data collected with the questionnaires, we used Pearson coefficient.

3. Results

3.1. VR prototype

The first outcome of this study is a VR game prototype. The game is currently available on Meta Quest 3 headsets and is distributed locally.

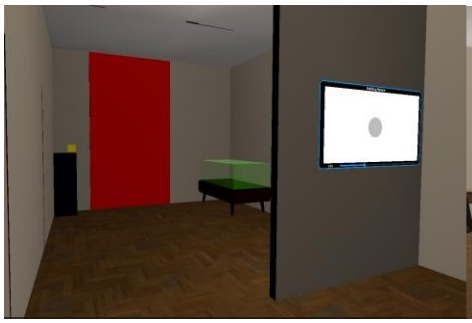

Figure 3

Figure 4

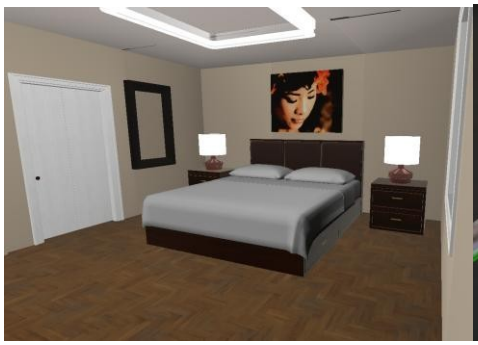

Figure 5

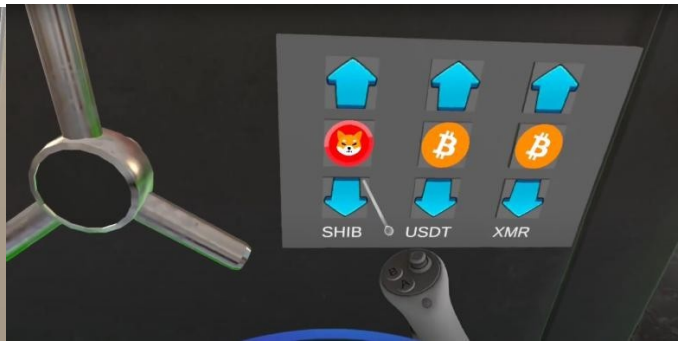

Figure 6

The game consists of the tutorial level and the search level. The tutorial level was built with LBD concept in mind, and it provides an in-depth guide on basic controls with concrete steps, actions, accompanied by videos (Figure 3). At the end there is a museum room that essentially reproduces the section of the checklist about hardware wallets, mnemonics and cards. There players can grab these items they are supposed to find during the real search and examine them in a 3D environment. This level is optional and is a little bit behind in the case of some features. The search level spawns players in the living room (Figure 4: left). The level apart from the living room also consists of the kitchen (Figure 4: right), bedroom (Figure 5) and several small rooms, one of each has a safe (Figure 6). There is a table marked with green in the center of the living room. Players bring the items they find on the table. The living room also contains a TV where players can indicate that they are done with the search and receive their final score. Apart from different items, both crypto and non-crypto related that can be found in the living room, there is a key hidden that opens a door to a living room which is rich in items. Paintings can be picked up, put back on their original places, and there might be hidden items behind them. The safe is locked with a password that is randomly generated each game session. There are 3 password elements – 3 cryptocurrency names are displayed on the safe and players must pick icons matching the

names of cryptocurrencies. Only then can the safe be opened to obtain all the valuables. Kitchen has little crypto related items but there are many places where players look for these items while most of the needed items in the living room are more visible.

Initially, players could move in the game using a locomotion system, when they use a joystick of a controller to move smoothly to the desired direction that somewhat resembles real human walking. Despite initial recommendations from experts to stick to teleportation, we stuck initially with the locomotion system as it makes the experience feel more immersive and natural and was more comfortable in terms of development process and item management for players. We underestimated the dizziness effect that would affect players if smooth game performance, nice graphics and relatively short play sessions compensate for that but at the end of the day a lot of research participants felt dizzy. That made us change the movement system to the teleportation and players started complaining about dizziness less often. Making such a switch required adjusting the level structure in the way that players could not teleport in unwanted placed ad get stuck which was not possible with locomotion.

Other game mechanics of the game include grabbing and throwing objects, realistic object behavior, ability to open and close doors and drawers, press the buttons to switch the lights on and off and open the safe, usage of the inventory represented by 5 bubbles that store items, crouch to get items that are located low easier. You can find more about game mechanics and game design in Appendix V.

3.2. Checklist – VR comparison

From that data we saw that people who read through crypto currency checklist scored on average 3 points in the questionnaire more than people who played the VR game prior to completing the questionnaire. This study suggests, with a given scope and conditions, that the cryptocurrency checklist was more effective than the VR prototype to increase the knowledge of.

Respondents who began on the checklist and filled in the questionnaire achieved the highest mean score (M = 15.7; SD = 3.30; *n* = 10) as shown in Figure 7 (Column 1). The same people then played a VR game before reading through the checklist and filled in the same questionnaire. Their performance dropped (M = 14.9; SD = 3.44; n = 9; Column 2). After running an unpaired t-test on the raw data of these 2 groups, we spotted that the difference in scores is not statistically significant ($t = 0.52$; $df = 17$; $p = 0.607$). The results show that under tested conditions, both methods led to comparable learning performance.

Notable, respondents who started with the VR game demonstrated the lowest score (M = 12.7; SD = 4.27; n = 9; Column 3). However, when the checklist preceded the VR activity, performance improved again (M = 15.3, SD = 3.02; n = 10; Column 4), approaching the initial high scores. After running a t-test on these data sets, we again see no significant statistical difference between the two groups ($t = 1.56$; $df = 17$; $p = 0.136$).

We can clearly see that the interquartile range (IQR) narrowed from 4.75 to 2.75 for respondents who were first exposed to the checklist and then followed with VR experience. Similarly, the respondents who started with VR and then read the checklist indicated that the IQR narrowed from 4.25 to 3.5.

Figure 7 also illustrates the range of scores by using “whiskers”. We see that the third column that represents respondents’ scores who started with VR experience, shows big score dispersion. This can be explained that some people got uncomfortable and lost with the VR while some scored a lot. In contrast, the checklist followed by the VR condition yielded the most consistent results, with the smallest range while having only a single outlier.

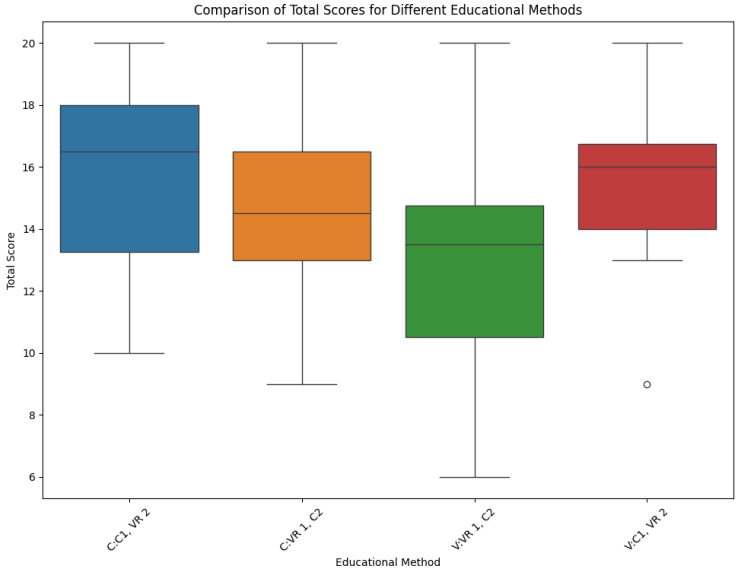

Figure 7(“C:” – results of a checklist; “V:” – results of the VR, followed by the order of the methods)

The results of the questionnaire also show that the research participants generally enjoyed the VR experience a little bit more than the checklist, experienced a slightly bigger level of focus and are more willing to use VR for their education in future (Figure 8). At the same time, the research participants indicate that the information about the cryptocurrencies was presented nearly equally clearly. In addition, the participants did not feel that their knowledge of cryptocurrencies did not change significantly.

Similarly, a t-test was conducted to compare how enjoyable participants found both learning methos and whether the difference is statistically significant. The results showed no statistically significant difference between two groups ($t = 0.96$; $p = 0.343$).

The t-test on the level of focus revealed a statistically significant difference between two groups ($t = 2.12$; $p = 0.041$). Participants reported higher levels of focus with the VR method (M = 7.21; SD = 1.81; n = 19) compared to those in the checklist group (M = 6.05; SD = 1.54; n = 19). This suggests that the VR experience was more effective in maintaining focus among the participants.

Lastly, the t-test was conducted on two data sets representing the reported willingness to learn in future with each learning method. The test revealed the difference to be very statistically significant ($t = 3.4$; $p = 0.0017$). The research participants reported a significantly higher willingness to continue learning in general with the VR experience (M = 8.05; SD = 1.43; n = 19) than with the checklist (M = 6.26; SD = 1.79; n = 19).

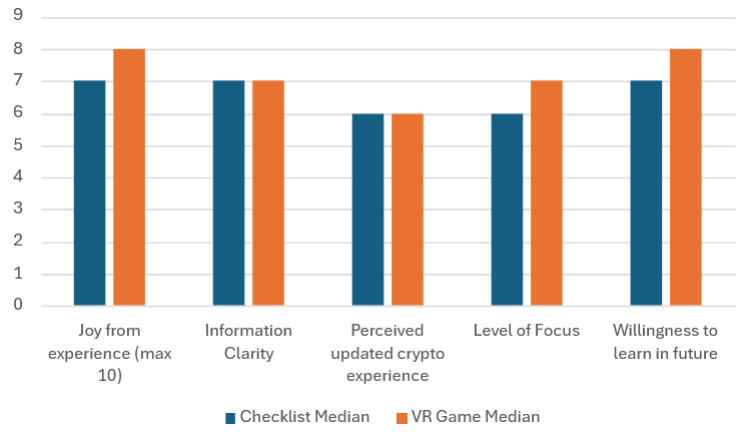

Figure 8

In addition, participants were asked to provide open feedback about their experiences with both the checklist and the VR prototype. These insights help to contextualize the results and offer valuable perspectives on user satisfaction and design considerations.

For the checklist, participants in general appreciated its clear structure, short length, and proper use of images to explain certain topics. Many pointed out that the visual examples clarified the different types of wallets. However, the language used in the document felt too technical for the beginners and had some struggles in remembering information from static text alone. Others stated that despite generally

good readability of the document, it may not be the most engaging format for remembering the learning material in long-term.

Feedback on the VR prototype was more diverse. Participants enjoyed the hands-on nature of the experience, especially the ability to realistically interact with items, walk through virtual environments, and apply what they learned immediately. Several respondents noted that such an immersive approach helped them recognize and remember physical properties of cryptocurrency devices. However, it was common for the participants to feel dizziness, experience unfamiliarity with VR controls, which also led to occasional difficulties of interaction with in-game elements. Some respondents also mentioned that the mini museum room with crypto-related items could be easily to overlooked if in rush.

Overall, the VR experience appeared to trigger stronger emotional and cognitive engagement, which was reflected into our statistical findings on level of focus and willingness to learn. However, the degree of comfort varied, which suggests us that VR needs be carefully designed to support novice users and ideally combine the VR experience with simpler and more traditional learning methods like the checklist for maximization of the results.

Part of the questionnaire was designed to discover respondents' impressions regarding each learning method and record their preferred learning method. This helped us to realize why people scored the certain way and to find some correlations.

Figure 9 illustrates the personal preferences of the respondents regarding their favorite learning method. More than half of the respondents prefer VR game over the checklist, while 20% prefer the checklist and the remaining have either no clear preference or dislike both methods.

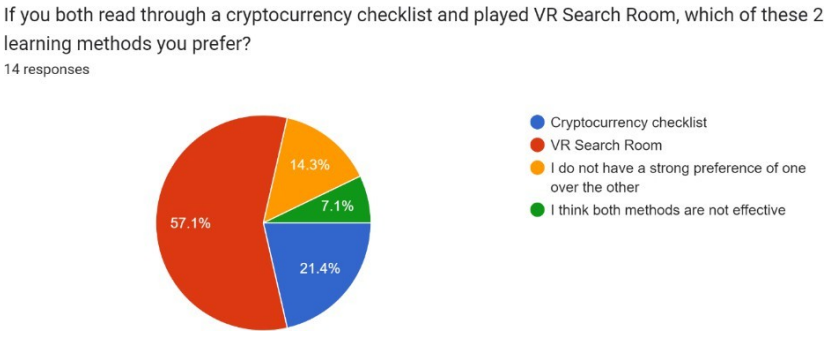

Figure 9

3.3. Target audience

As stated in the game design document (see Appendix V), the VR prototype was created mainly for the FIOD employees who have limited experience in videogames and especially VR games. With the help of the questionnaire, we have collected data about who the people in our target audience are.

Figure 10 illustrates how respondents estimated their knowledge of the topic of cryptocurrencies. The median value was 5. So, in general respondents have average knowledge of the topic before learning anything from our research. However, the spread of values is noticeable as 5 people rated their knowledge as lower than 4 and 4 people rated their knowledge more than 6.

Not everyone is equally familiar with video games, especially VR games and Figure 11 illustrates that. The median value for experience in video games is 4. This shows that respondents in general are not experienced with video games. Although, there are 4 people who rate their experience with games as 9 out of 10.

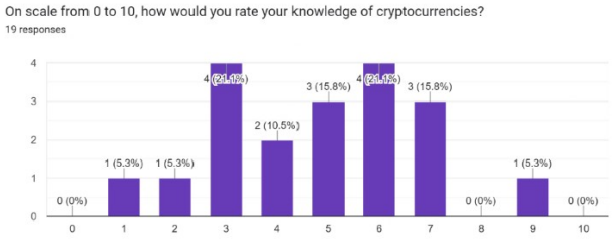

Figure 10

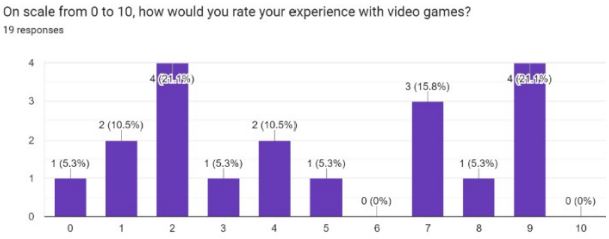

Figure 11

Figure 12 illustrates the age of the respondents. The ages of the respondents vary but the biggest age group is 25–34-year-olds.

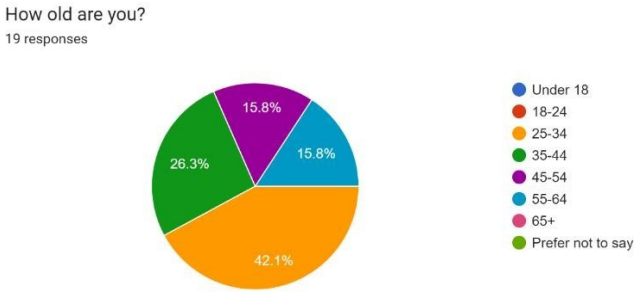

Figure 12

We defined Pearson correlation coefficients to find the possible correlations between different data entries we received from the research participants. the age of the respondents and their score. Regarding the correlation between the age of the respondents and their score for the checklist results,

the correlation is weak and insignificant (r = 0.075). For the results after doing the VR experience, we found a somewhat stronger correlation between age and the final score than with the checklist, but still rather weak correlation (r = 0.1206) which suggests that age did not influence the score significantly.

There appears to be a moderately strong positive correlation between the estimated cryptocurrency knowledge of the participants and their score in the questionnaire after reading the checklist (r = 0.63) which suggests that people who knew more about cryptocurrencies before in general scored more in the questionnaire. This also suggests that the questionnaire that we designed indeed measures the knowledge of the cryptocurrencies somewhat accurately. We spotted a bit weaker but still moderately strong positive correlation for the VR experience (r = 0.46). The cryptocurrency experience matters in both cases and a bit less with the VR experience, possibly because of its novelty to the participants.

We also found a weak to moderate positive correlation between how experienced participants were with gaming and their final score in the questionnaire after the VR experience (r = 0.34). People are more experienced with gaming scores in general, slightly more than those who have less experience with videogames. The correlation could be even stronger if we used a desktop serious game for example, as the novelty of VR to most participants influenced the score (only 3 people had some VR experience before).

4. Discussions

Comparing which learning method is better was not entirely reasonable. Both methods have their strength and weaknesses. The checklist is way more accessible and straightforward than the VR. At the same time, VR is more engaging, immersive, motivating and can simulate almost any situation possible. Rather than directly comparing these two methods, they should be used together to complement each other and ensure the maximum learning effect. But if any relevant comparison is to be made, then instead of a serious VR game there should be a serious desktop or mobile game. That equalizes the complexity of the interaction a lot which makes the comparison of two methods more reasonable.

There are several reasons why VR showed slightly less significant results based on the final score. The questionnaire structurally reminds the checklist, so there are more links between the information written in the checklist and what needs to be answered in the questionnaire. Moreover, even though it was not captured by the questionnaire, most of the respondents (about 17) had absolutely no experience with the VR even though the mean of the overall experience with videogames in general is moderate (M = 4). We were expecting that the respondents would be quite new to the VR which is why they were presented with an extensive game tutorial. Such a tutorial in combination with the locomotion could tire the respondents and drive their focus away from the main learning objective, which is learning more about cryptocurrencies, and put a solid portion of their focus to learning basic controls in the VR and orientation in space.

Moreover, the questionnaire as a measurement tool is a quick and easy tool to evaluate knowledge of the cryptocurrencies but not necessarily the most suitable in case of FIOD. The knowledge of cryptocurrencies must have a practical application. One practical application is finding the crypto related items in the real suspect's apartment or in the real-life 3D training facility. Our assumption is that instead of measuring knowledge of cryptocurrencies with the questionnaire, it would be measured by how well FIOD employees conduct the search in the training facility, meaning that the more hiding spots and the crypto related items they seize, the higher score they obtain. We believe that with the best practices applied to the VR prototype and the search at the training facility to be used as a final performance measurement tool, then the respondents would score significantly more with the VR prototype than with the checklist. But the maximum possible score would be initial training in a VR prototype and then conducting a search in the training facility while having the checklist with them.

What is more, with a small sample size (n = 19) we get a noticeable margin of error – 22.48%. That suggests that the precision of our results is low. It is advised to do further research with a larger sample size, more longitudinal testing, improved technical state of the VR prototype, and more diversified samples.

5. Conclusion

This research aimed to compare the effectiveness of a serious VR game and a traditional checklist (PDF) in teaching cryptocurrency concepts. While the checklist produced slightly higher average scores in the questionnaire, the difference between two learning methods was not statistically significant. Which suggests that both methods had similar effectiveness in supporting short -term learning acquisitions under the tested conditions.

However, open feedback from the participants together with secondary results revealed interesting insights. The VR experience demonstrated significantly higher perceived levels of focus and stronger willingness to continue learning via that method in future not only regarding cryptocurrencies but for other topics as well. This indicates that the VR may be a more engaging and motivating tool for education despite originally slightly lower scores due to the tested conditions. While improving learners' involvement, the VR also introduced some usability challenges, like motion sickness and varied outcomes, mostly among less experienced users.

Our correlation analysis revealed that higher prior knowledge of cryptocurrencies was moderately related with higher questionnaire scores in both methods, and stronger in the checklist condition. The familiarity with videogames also showed moderate but weaker correlation with score for the VR experiences. Also, knowing that there is no noticeable correlation between participants' age and score, the prior knowledge of the topic influences the score more than gaming experience and age. Our findings imply that the VR approach instead of direct comparison with other methods to pick only one most effective, should be used in tandem with more traditional learning methods, like the cryptocurrency PDF or paper formatted checklist. The VR learning method is a nice addition to other learning methods and should not be aimed to entirely replace other learning methods.

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7. Appendices

Appendix I

Meeting Notes Mario

Date: 10.09.2024

Time: 11:00 – 12:00

Location: Fontys TQ5

Attendees: Mario Paiano, Dmytro Pakhuta

Purpose: General directions on the VR development

Key Discussion Points

Topic 1: Tips for VR environments

- Give players hints
- Use mood boards
- Build floor plans first and then building the level itself
- Use little text and more audio
- Stick to 3-4 rooms in one level
- Place most of the interactive objects near the eye level

Topic 2: Help from other developers

- Search for Dilmer Valecillos – Unity XR expert
- Contact BlueTea for their expertise in development and their tool – Virtual Studio

Topic 3: Ideas for the game

- Keep it simple, realistic, not too creative
- The idea of the game heavily depends on the stakeholders' requirements. Speak to them.

Appendix II

BlueTea Meeting Notes

Date: 16.10.2024

Time: 10:00 – 12:00

Location: Kapellerpoort 1, Roermond

Attendees: Dirk Bongers, Dmytro Pakhuta, Henry Siero

Purpose: discuss functionality and plans of the tool Virtual Studio, multiplayer or singleplayer in serious games, VR vs non-VR

Key Discussion Points

Topic 1: Virtual Studio

Virtual Studio is a web application and a set of Unity plugins that makes development and management of Unity projects easier, especially for non-programmers. A set of Unity plugins adds certain programming libraries that help define key objects and actions that designers will operate within the web interface. With such an approach, people can define scoring rules, actions rules, level flows in the web interface and it will send execution instructions to Unity. This makes the whole understanding of the game more visual and modular. FIOD is interested in buying a plan for such a tool as it sees the potential of how it can be useful for the future of the project.

Topic 2: Singleplayer vs multiplayer for serious games

Both options are possible even using Virtual Studio. BlueTea has also built their own multiplayer games but not with VR. Dirk's suggestion for the project of FIOD to use a single-player solution. For such a serious game it is important to monitor the activities and timing of the player, keeping the score and making sure the environment reacts properly. These measurements double, triple, quadruple depending on the number of players in a multiplayer solution. Such changes in the game's state are very difficult to keep track of.

Topic 3: VR or non-VR?

Whether the game should be in VR or not depends on many things. The purpose of the game determines the list of devices and platforms needed. If the game needs to immerse players deeply into the game's world, for example surgeon simulator, fire safety training simulation or any other simulation that intends to train both motoric skills and situational awareness, then VR is a good option. In any other case, VR is less accessible than mobile and desktop devices, more difficult to develop and support, more difficult to use,

requires more space, cannot handle too much UI with text which can be often necessary. So, usually the advice is to stay away from VR unless there is a need for strong immersion.

Appendix III

Meeting Notes: KMAR

Meeting Information

Date: 30.10.2024

Time: 10:00 – 12:00

Location: Koning Willem III-kazerne, Frankenlaan 70, 7312 TG Apeldoorn

Attendees: Mathijs Koster, Ted van Diepen, Melissa Driessen, Dmytro Pakhuta, Henry Siero.

Purpose: prototype review, sharing research information about VR in education, possible assistance in prototype creation.

Key Discussion Points

Topic 1: Experience of using VR experiences at KMAR

KMAR has a training center where they actively use VR in the education of their recruits. They use various games that they created for different purposes. KMAR did their own research on how effective VR is compared to paper instructions. More than 75% of testers of age 17-21 liked the VR gaming experience in general and more than using paper instructions and checklists and showed better results. Around 20% of testers suggested certain improvements to the VR experience. The rest did not enjoy the VR experience or try it at all. The details of this study are not shared with FIOD at the moment.

Topic 2: Suggested help from KMAR

As KMAR has more than 30 game developers in their office, they offered FIOD help with making 3D models of objects that Dmytro and Henry could not find for free on the Internet. That would save FIOD time and money.

Appendix IV

Meeting Notes: Mario & Mark

Meeting Information

Date: 13.11.2024

Time: 09:30 – 12:00

Location: Fontys University building, Eindhoven

Attendees: Mario Paiano (online), Mark Mettsen, Dmytro Pakhuta, Henry Siero

Purpose: prototype review, tips on player movement, preventing dizziness for players, research tips, correct representation of certain elements in VR for optimal learning efficiency.

Key Discussion Points

Topic 1: Locomotion VS Teleportation

- It was suggested to completely get rid of the locomotion system and leave just teleportation. Even though the tunneling vignette was applied to reduce players' dizziness during locomotion and it did reduce some dizziness, having just teleportation as the only game mechanic that players use to move around the virtual world will reduce dizziness even more.
- As a follow-up, we must give teleportation a chance to be the only way to navigate the game levels.

Topic 2: Optimal controls layout

- It was suggested to have movement and grabbing logic to be on separate controllers unlike it was before when grabbing was assigned to both left and right controllers while movement was also assigned to the left controller. As an example, players could teleport using the left controller and grab with the right controller. That could be switched for left-handed people. Although, exceptions could be made for heavy objects that require 2 hands to grab them.
- As a follow up, we should experiment with controls and minimize their distribution. But we also might not add a need to add heavy objects to the game that players can carry only if they grab them with both controllers as this may add more unnecessary complexity.

Topic 3: Uncomfortable height of some objects

- Depending on the player, the game could calibrate its height in such a way that some people could not grab certain objects without them standing up from a chair or crouching in real life. Our question was how to prevent that
- It was suggested to calibrate the height in the editor after more experiments with real people
- As a follow up, we considered adding a desired button for the game character to crouch. That way players do not need to leave their chair to get the object that is located low. For the objects that are too high, we started considering adding a possibility to teleport on top of the chair to get a high ground which would prevent players from standing up in real life.

Topic 4: Grabbing

- Mario and Mark pointed out that the haptic feedback that the prototype has when players grab objects is a good thing to have. But they also noticed that the ability to grab objects from a distance will make the game less interesting and dynamic and suggested leaving only the close distance grab. This will open opportunities for more space-related puzzles.
- As we need to make sure to keep balance between ease of use for the controls and immersive gaming experience, further experiments with game mechanics are required.

Topic 5: Tutorials

- It was suggested for the tutorials to make a set of small rooms where there is nothing that distracts players from learning specific game mechanics. For example, there is a room in a tutorial that teaches players opening locked doors with keys. The room should be empty and contain no other objects than a locked door and a key. Also, according to Mario, tutorials can and should briefly explain possibilities of the game but do not show absolutely everything, every nuance.
- We took this into consideration for further tutorial level design.

Topic 6: Fair comparison of Cryptocurrency Checklist and VR game

- It was suggested the questionnaires that test the knowledge of crypto after reading through the checklist and playing the VR game should ask questions so that research participants can find right answers in both of the products. For example, the questionnaire asks to pick all images that depict a valid real-world cryptocurrency. Participants can read through the section in the checklist where various cryptocurrencies are mentioned with pictures. The same information should be found in

the VR game. Mario also suggested using the capabilities of VR even for presenting the questionnaire. Instead of players first going through the VR game and then filling in the questionnaire answers on paper or the computer, it might be more interesting to make players fill in their answers in VR with usage of physics. That way players remain in the environment and have more correlation with what they have learnt in the VR experience.

- We took the advice regarding proper questions for the questionnaire into further consideration. Checklist and the VR game should have similar information they are trying to teach, which is then used in the questionnaire. And although filling in the questionnaire in the VR environment sounds entertaining and reasonable, we think that a lot of players will be already tired after completing the level and this might affect their ability to answer questions in VR correctly and we might want to leave that idea out.

Topic 7: Creative presentation of information

- Some information is easier to show on paper than in VR. For example, a list of cryptocurrencies with their icons can be presented well on paper, and VR is unnecessary for that. But Mario suggested a creative way of checking players' knowledge even with this data. The idea is to have a safe with a lock. The lock can be opened with a password. Traditionally, it is a numeric password of 3 or more elements. Correct numbers can be found in other parts of the level. But in this case numbers can be replaced with crypto currency icons. For every element, there is a crypto abbreviation, for example XMR, and players need to find the corresponding icon for each element. The benefit of such system is that even if players are not sure about some puzzle elements, like they do not know how XMR coin icon looks like, they can still guess it and once that happened and the safe is opened, they see what icon XMR has and have a good chance to remember that.
- We really liked this idea and have serious intentions of implementing it.

Other

- It was suggested that the same goal (for example, getting inside a locked room) could be achieved in several ways. For example, players could find a key to open the locked door or find an axe and destroy the door. But this could be too much for the project scope

Future work

Analysis room

As an alternative to the inventory system, players can teleport to the separate room where they put all their collected items where then they sort them and get feedback on every item they have sorted. This will be different from the current system when players see only the final score, but they do not know about their mistakes per item. Such room can give explanations for every item, what those are, so that the knowledge is updated for the players regarding cryptocurrencies.

More levels

When all elements of the game are ready, it will be a good idea to create more levels with different complexity, different items, and their location. That will also allow us to build up the level of difficulty in a smooth and organic way.

Table of scores

Scores that players get should be recorded in a database and displayed after each play session. That way players realize how good or bad they played compared to others. This often stimulates competitiveness and willingness to improve.

Audio improvements

Add music, more sounds, for example opening doors and drawers, sound for teleportation when it is finished, object collision sound. And it would be optimal to use text-to-speech hints as well.

More items

Some rooms are filled with various items and some are lacking items. Adding more items would make the game feel more realistic and will confuse players more, because with more items they have more space for making mistakes. But it should not be overdone to prevent unpredictable physics behavior and performance drops.