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**Extending the VREX toolbox for studying false
memory in virtual reality**

Bachelor's Thesis (9 ECTS)

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Tartu 2016

Extending the VREX toolbox for studying false memory in virtual reality.

Abstract:

False memory is a psychological phenomenon in which a memory is recalled which did not actually occur. There have been several studies on false memories. However there has been only one notable study using virtual reality. With the advancements in virtual reality it is more advantageous than ever to perform psychological experiments in virtual reality rather than using conventional methods. The aim of this thesis is to create an experimental module in the VREX toolbox for studying false memories and add on already existing capabilities of the toolbox. The experimental module adds to the toolbox the possibility to place the subject in different rooms where some change has been made. Also, additional object manipulations were added to the VREX toolbox. The additions are created in a manner that allows them to be easily used in future experiments. On top of that, the output was modified so that it fits the capabilities added in this thesis. The present work opens up the possibility to rigorously study false memories in virtual reality.

Keywords:

Virtual Reality, False Memory, VREX

CERCS: P175

VREX tööriistakasti laiendamine valemälestuste uurimiseks virtuaalreaalsuses

Lühikokkuvõte:

Võltsmälestus on psühholoogiline nähtus, kus isik meenutab mälestust mida tegelikkuses pole toimunud. Võltsmälestuste uurimiseks on läbi viidud mitmeid uuringuid, kuid seni on olnud ainult üks märkimisväärne võltsmälestuste uuring, kus kasutati virtuaalreaalsust. Tänu virtuaalreaalsuse kiirele arengule on praegu soodsam kui kunagi varem viia läbi psühholoogia eksperimente virtuaalreaalsuses mitte enam tavapärastes katsekeskkondades. Selle lõputöö eesmärk on luua eksperimentaalne moodul VREX tööriistakastis võltsmälestuste uurimiseks

ja laiendada tööriistakasti olemasolevaid võimalusi. Eksperimentaalne moodul lisab tööriistakastile võimaluse paigutada katseisik eraldatud ruumidesse, kus mingi muutus võib olla toimunud. On ka täiendatud objektide muutmise võimalusi. Täiendused on loodud viisil, mis võimaldab neid lihtsasti kasutada tuleviku eksperimentides. Peale selle on väljundfaili muudetud nii, et see võimaldaks salvestada muutuste põhjal saadud andmeid. Käesolev töö avab võimaluse põhjalikult uurida võltsmälestusi virtuaalreaalsuses.

Võtmesõnad:

Virtuaalreaalsus, Võltsmälestused, VREX

CERCS: P175

Table of Contents

Introduction

2 Background and related work

2.1 False memory

2.1.1 Concept

2.1.2 Previous studies on false memory

2.1.3 Practical impact

2.2 Virtual reality and used technologies

2.2.1 Use of virtual reality devices

2.2.2 Oculus Rift

2.2.3. Advantages of using virtual reality for studying false memories

2.2.4 Previous studies about false memory using virtual reality

3. Toolbox

3.1 Previous version

3.2 False Memory experiment

3.2.1 Procedure

3.2.2 Object manipulation additions

3.2.3 Field of view

3.2.4 Output file additions

4. General Discussion

4.1 Current limitations of the Toolbox

4.2 Future work

5. Conclusion

References

Appendix

I Code

II Licence

1. Introduction

False memory is a psychological phenomenon in which a memory that did not really occur is recalled [1]. Our memories are not fixed, they can be lost, changed or even new ones can be created [3]. What makes this phenomenon increasingly interesting is the fact that we are confident in our memories and sometimes will not notice the occurrence of false memories. This phenomenon brings up the question of credibility of witness testimony and our memory in general. For example in 1984 a man by the name Kirk Bloodsworth was sentenced to the gas chamber. He was convicted for the rape and murder of a nine-year-old girl. This conviction was based on the testimonies of five eyewitnesses. Nine years later Kirk Bloodsworth was proven innocent by a DNA test. The case of Kirk Bloodsworth is not one isolated example. The identification process generally involves a sketch or selecting the alleged culprit from a police line-up. The eyewitness can falsely remember some characteristics and recall a similar face to that of the actual perpetrator. Due to its importance and fallible nature of our memory, it is interesting to study the phenomenon in controllable, but realistic setting. Thanks to advancements in virtual reality conducting such research has become much easier.

Currently there are several methods to study false memory. The best way to form false memories is with the use of fake photographs[3]. For example in one experiment a part of a picture from participant's childhood was added to a picture of a hot air balloon ride (Figure 1). The fake photographs of participants created false memories about the event.



Figure 1: Fake photographs used to create false memories [1]

For example in a study conducted by Grinley several fake photographs were shown of Warner Bros. cartoon character Bugs Bunny in Disneyland. In reality Bugs Bunny is owned by Warner Bros. thus it would not appear in Disneyland. These photographs created a false association of the character with Disney. Participants were then asked to recall their meeting with the character during their visit to Disneyland. 25 to 35% of participants claimed to have met the character[3].

While the study is very interesting, its setting is hardly controlled. Although it is possible to conduct such experiment in a controlled and realistic setting it would be costly and require a lot of time in order to reproduce it every experiment. One modern way to solve this problem would be to conduct such experiments in virtual environments.

To this date there has been one notable experiment for studying the phenomenon in virtual reality (see chapter 2.2.4), which does not use the current capabilities of virtual reality. To improve immersion in the environment a head mounted display might be used. This technology allows user to see a 3D generated environment. Head mounted displays also track head movements, which allows the user to look around in the generated environment.

The main goal of this thesis is to create an experiment with an easily controllable environment to learn more about false memories using a previously developed toolbox for

creating virtual reality environments for memory research (VREX) [17,19]. VREX enables to create memory experiments in virtual reality. It has experiments to research change blindness and memory. On top of previous capabilities of the toolbox a wider variety of object and memory recall manipulation is provided.

Second chapter describes false memories, related studies both with and without the use of virtual reality and other technologies.

Third chapter briefly describes capabilities of the toolbox, what was added and how a researcher can use the experiments.

Fourth chapter is general discussion. The current state of the toolbox, problems that occurred in the development stage, use of virtual reality and future directions.

2 Background and related work

2.1 False memory

This chapter focuses on false memory, methods of studying false memory and the impact of false memory on our lives.

2.1.1 Concept

False memory is the psychological phenomenon in which a person recalls a memory that did not actually occur. The most basic example would be a person placing their keys on the fridge and when recalling their location would look on top of the cabinet, which might be caused by the person reconstructing the memory from the motion of placing keys on a high surface. False memories are believed to be very common, but due to us being unable to identify them they often go unnoticed. Currently, there is still no conclusive way to distinguish between true and false memories only based on the subjective report about a memory [2]. The main method of creating a false memory is to give a believable stimulus. Fake photographs, similar setting or even emphasising words in a misleading question during memory recall process can create false memories[3].

2.1.2 Previous studies on false memory

First notable study was done by E. Loftus and J. Palmer called (1974) *Reconstruction of Automobile Destruction* [4]. The aim of the study was to see if language used while questioning would alter the eyewitness testimony. The experiment study proceeded as follows. Forty-five students were subjects of this experiment. Subjects were shown short films between five to thirty seconds long of traffic accidents. After that subjects were asked to recall the speed at which vehicles were moving. The false memories were created by manipulating verbs used in questions. For example one question was “How fast were the cars going when they hit each other? ”. In other questions the verb “hit” was replaced by verbs: smashed, bumped, contacted. The results showed that estimated average speed was affected by the verb used in the question.

There are many other notable examples of studies done on the phenomenon, which all share one common characteristic described by quote from Z. Faulkner and E. Leaver study: “Results indicated that positive and negative events can be implanted at an impressively high rate and with a very simple manipulation [2].”

2.1.3 Practical impact

Most notable impact of the phenomenon is on eyewitness accounts. Current justice system has uncritical acceptance of eyewitness accounts due to misconceptions about our memory. Our memory is not a camera recording. Article in Scientific American claims that Innocence Project researches have reported that 73 percent of the 239 convictions overturned through DNA testing were based on eyewitness testimony. [5,6]

2.2 Virtual reality and used technologies

This chapter focuses on use of virtual reality, virtual reality in memory studies and virtual reality devices. Virtual reality is a combination of computer generated environments and specific hardware, so that the users would feel themselves as a part of this reality.

2.2.1 Use of virtual reality devices

Virtual reality is widely used to replicate real life situations. Virtual reality is gaining popularity in many fields such as education, fashion, healthcare, military, engineering, sports, entertainment and film. It is commonly used in simulators to prepare for situations that do not allow trial and error approach, such as aviation and cosmonautics. [9]. In this study head-mounted device with head tracking and stereoscopic displays, one for each eye, is used to imitate reality.

2.2.2 Oculus Rift

This study requires the use of a head mounted device such as Oculus Rift. Oculus rift is a virtual reality headset. There have been several versions of the device that have been released. The oldest one being Development Kit 1 (DK1) followed by Development Kit 2 (DK2) (Figure 2.)which is followed by recently released consumer version. The experiment done in this thesis has mainly been tested on DK2, however it should work on all newer

Oculus Rift devices. Oculus Rift allows to create realistic experiences, because it creates 3-dimensional vision thanks to its 1080x1200 resolution display and 110 degree field of view[10].



Figure 2: Oculus Rift DK2 [11]

2.2.3. Advantages of using virtual reality for studying false memories

Conventional means of studying false memories use either lists of words like DRM paradigm or fake photographs, but rarely fake environments to create false memories. That is because creating such environments is very time consuming and costly. For example creating an environment with 3 rooms and sending participants through them first to memorize them later to see if anything was changed would take a tremendous amount of time compared to conducting the experiments in virtual reality. Virtual environments could provide us with a whole new opportunity on false memory creation and study. On top of that experiments in virtual reality can be precisely recreated later, because all the environments and their variations can be saved and loaded any time. Carrying out a similar task in real world would

be extremely difficult. In addition there are no distracting or unexpected factors in virtual reality. For example a bird slamming into the window would break subject's concentration, but in VR such accidents are impossible. Lastly, according to American Psychology Association the more perceptual information a subject receives the more likely they are to believe that they experienced the event [15]. This brings a clear advantage of using VR opposed to fake photographs as in virtual reality subject has a feeling of being inside of the environment.

2.2.4 Previous studies about false memory using virtual reality

One previous key study, "Virtual reality for the study of true and false memory" was conducted in Paris Descartes University. In this study students were driven or drove around a virtual city (Figure 3).



Figure 3: View of the virtual city students were driven or drove around in [7].

The environment was created using Virtools. The only factor manipulated in the design was sensory-motor implication. Subjects in one group were driving the car, which ensured that the active component of the sensory-motor implication was filled. The true and false memory was tested by asking questions about a crash that occurred in the town. For example the test subjects had to recall the color of the pullover a person wore (Figure 4). Lastly all participants had to pass a DRM test (see below).

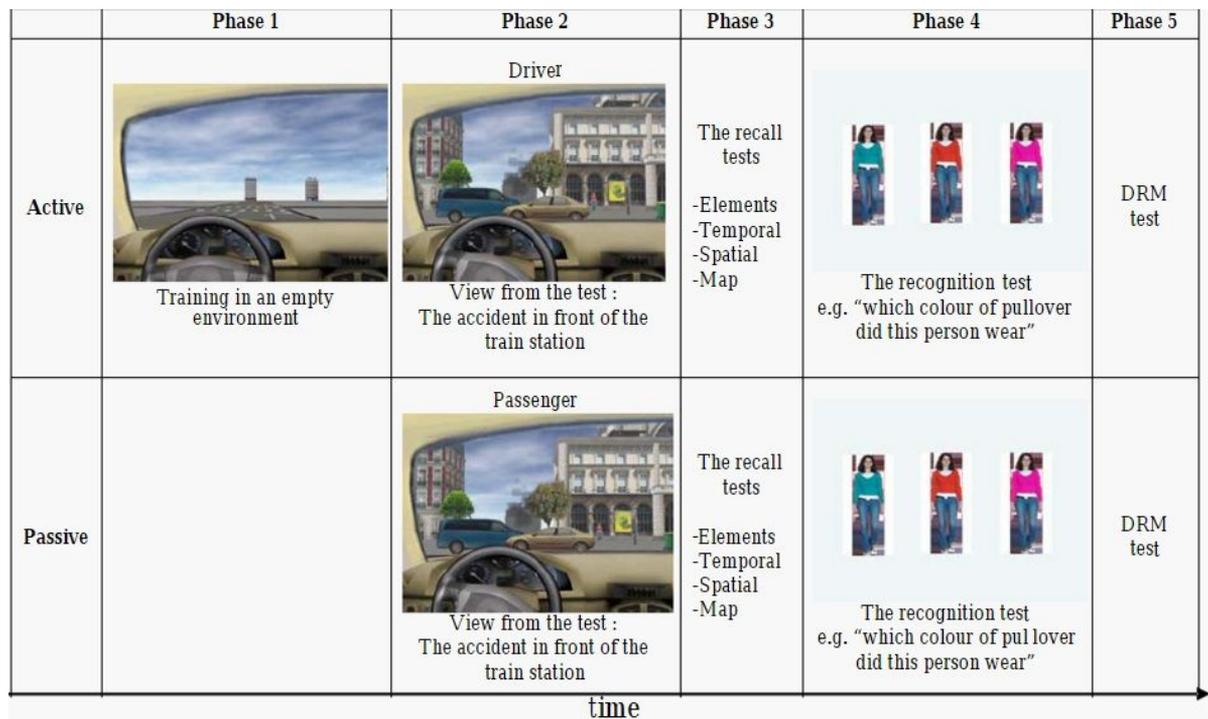


Figure 4: Scheme of the procedure that participants had to complete in the experiment [7].

DRM paradigm also known as Deese-Roediger-McDermott paradigm is yet another procedure used to study false memory in humans. In this procedure subjects have to memorise lists of words that are associated in some way (e.g. all are pieces of furniture) and as a test given a word from the same category (e.g. chair). Subjects have to distinguish the added new word[8]. The results in [7] showed that there was no correlation between false recognitions from the DRM paradigm and true recognitions of the town. However, the study was rather preliminary in nature, is still not published and, most crucially, failed to reliably induce false memory. In the present work we will develop immersive virtual environments

where a wide range of object properties can be a subject of change. Hence, the present work can aid a more thorough study of false memory.

3. Toolbox

3.1 Previous version

Previous version of the VREX-Toolbox allowed researchers to create basic experiments to study change blindness or memory. With the use of the toolbox researcher could design and conduct experiments on mentioned topics. To do so researcher could create a new level or choose one of the available ones and, if needed, modify it and set some experimental variables. For memory experiments, it was only possible to choose the type of the recall test at the end of the experiment. It was not possible to set the behaviour of objects in the virtual experimental rooms.[17]

3.2 False Memory experiment

3.2.1 Procedure

This experiment is created using the VREX-Toolbox for creating virtual reality environments for memory research. The experiment requires the use of Oculus Rift or HTC Vive virtual reality headset. To create the experiment researcher can create a new environment using the Toolbox or use already existing one and modify it to their needs. The researcher can modify various parameters of the false memory experiment. All parameters have default values in case the researcher does not enter some specific parameters .

The idea for experiment is based on quote of E.Loftus “One of the cleverest and most powerful techniques for planting highly implausible false memories involves the use of fake photographs [3].” Fake photographs have some static aspect of them changed, but in this experiment we use complex indoor environments. In this experiment some aspect of the room might be changed and the subject has to identify whether there is a change and what type of change was done in the room.

When the experiment starts the subject is allowed to walk around the rooms freely using the keyboard and the mouse. The subject has the task to memorize the environment during the time, which the researcher has set. After the initial stage the subject will be presented with the

same environment in the following way. The subject is allowed to move in one room at the time and has to identify whether something is different about that particular room. Once the subject has done identifying the changes the subject can proceed into the next room with a mouseclick. The differences in the environment before and after are created by manipulating objects (Figure 5). In both cases the subject is then presented with a response screen and can indicate whether anything changed and note the type of change.

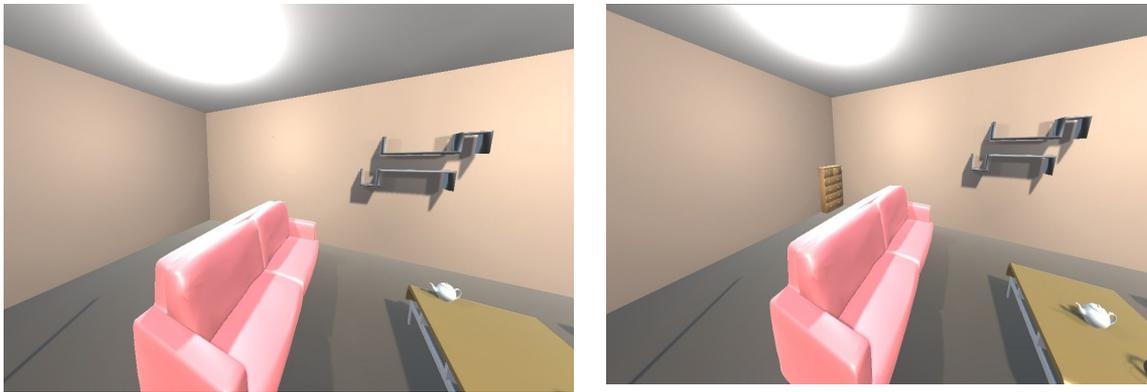


Figure 5: Example room originally (on the right) and after the object change (on the left)

3.2.2 Object manipulation additions

Object manipulation is done after the subject has walked around the environment and before the subject has to identify the differences in the environment, if there are any. Object can be translated, change color, swap positions with another object and be deleted from the

environment. Before the experiment the researcher can adjust and choose which object changes can happen in the environment (Figure 6).

Color change can be limited by the researcher. The researcher can set the range in which red, green and/or blue values of the color change. For example noting 10, 0 and 0 in the Color change menu (Figure 6) will make rather small changes to the original color. This is done to ensure that the researcher can control whether the change is drastic or not. This again allows to study whether and how false memories are dependent on the amount of color change.

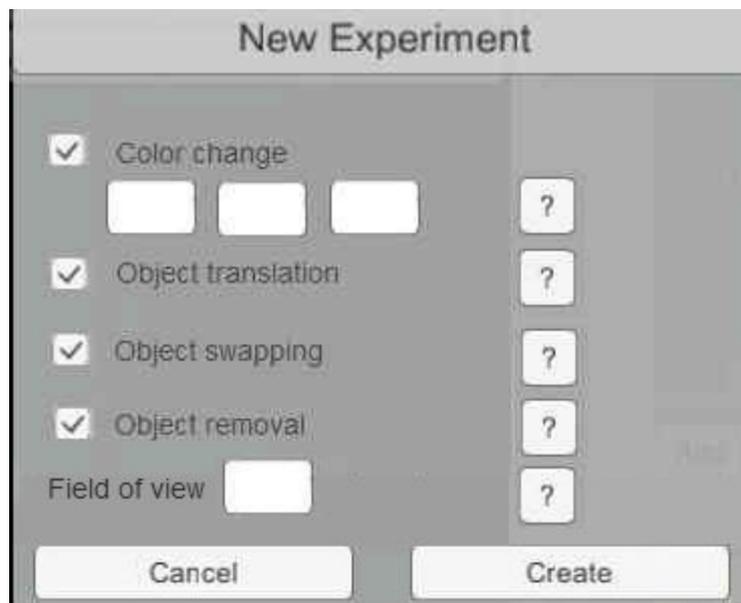


Figure 6: example of configuration menu

Objects will swap positions with other objects of the same type. For example wall mounted objects will not swap positions with chairs, but will swap positions with other wall mounted objects. The swapping also accounts for the initial rotations of the objects in the world space (Figure 7). This is done by categorizing objects by type and size and then swapping the positions of objects of similar type.



Figure 7: Example of objects swapping positions and color change

Pseudocode:

```

int l = distance to the next object on the left
int r = distance to the next object on the right
int f = distance to the next object in the forward direction
int b = distance to the next object in the backward direction
if (l > 20){ r = random [20,l] move object left by r units}
else if (r > 20){ r = random [20,r] move object right by r units}
else if (f > 20){ r = random [20,f] move object forward by r units}
else if (b > 20){ r = random [20,b] move object backward by r units}

```

Object translation is implemented by changing the value of gameobject's position variable if there is no other object obstructing the translation(Figure 8).



Figure 8. Object translation with right direction of the cupboard was not obstructed.

Object deletion is fairly simple. A random object will be deleted from a room depending on whether it was seen by the subject. The subject has an opportunity to inform if an object got deleted in the confirmation menu.

Pseudocode:

```
int i = new Random [0,objectsToChange.length]
objectsToChange[i].Destroy
```

3.2.3 Field of view

Both headsets provide about 110 degree field of view (FOV). In this experiment the researcher can also select the width of the field of view in which the object change will occur. For example if the researcher wants to know whether the subject has better true memory recall if objects that have been changed were at some point right in front of them. This is done using raycasting. Raycasting, as the name suggests is a process were invisible to the subject ray is cast to do detect the line of sight and perform angular calculations [16]. In the simplified visual representation of the idea (Figure 9) the light-gray area represents the field of view chosen by the researcher blue and red capsules represent objects. Only the objects in this area are added to the set. All the previous object changes have to be identified by the subject, who will then select the object and from a popup menu select the type of change

Pseudocode of the most important method to determine objects in the field of view.

Initialize list of visible targets

```
Initialize angle given by researcher
Initialize set of objects to change
Set findObjToChange(){
    Clear the list of targets
    Add all objects in view radius to the list
    for (object in list of targets){
        targetObject = targetsInView[object]
        if (angle of the vector from player to object >= given
angle){
            Add target object to the set.
        }
    }
    return set
}
```

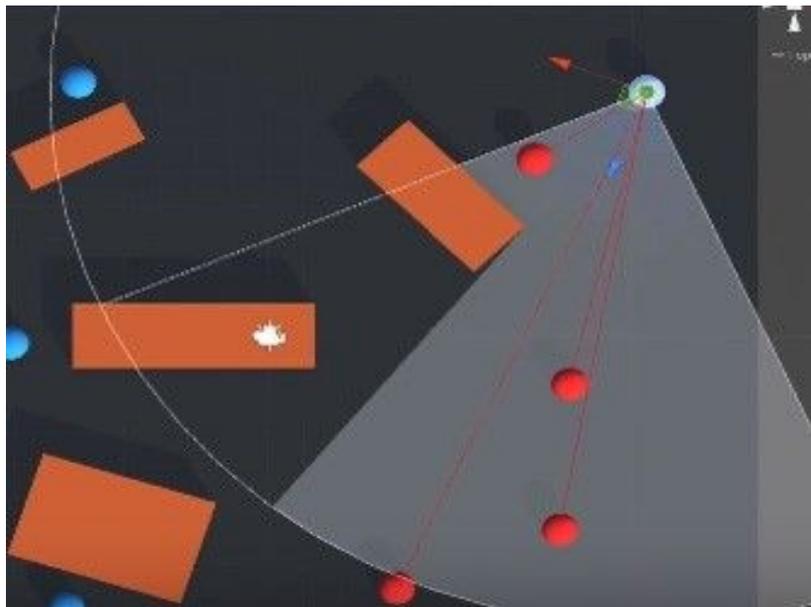


Figure 9: Visual representation of FOV limitation.

3.2.4 Output file additions

The output file is generated based on subject's performance during the experiment. It also has initial settings that were created by the researcher such as level name, correct guesses and incorrect guesses. On top of the number of guesses and the number of correct guesses, there is also information about them. If the guess was correct, the type of change is recorded in the output file. For example, if the subject identifies correctly that an object was moved, then the change type, the object that was changed and the true answer will be logged. If the guess was not correct then the type of change, if there is one, is recorded and the guess. For example, if the subject claims that object has changed color, although it has not, then the real change applied to the object, object's name and the false answer will be logged. If there have not been any changes to the object, it will be stated so instead of the change applied to the object. In case if the subject guesses that there are no changes in the room the subject will be moved to the next room and in case there were still changes they will be logged as incorrect with the claim parameter stating "none".

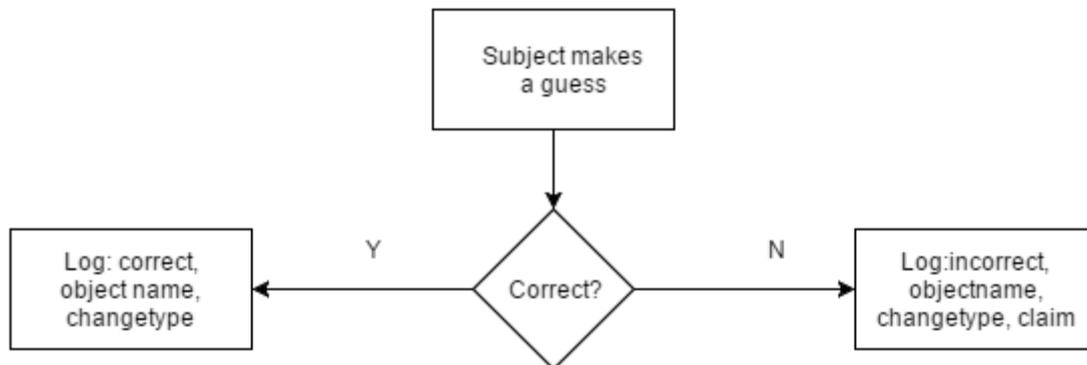


Figure 10: Flow Chart of output file generation

All the code can be found in Appendix II. For object changes navigate to assets, scripts, FM_scripts, FM_objectchange.

4. General Discussion

4.1 Current limitations of the Toolbox

The objective of the VREX Toolbox is to enable scientists to create their own experiments, but it has its limitations. Using the experiment template an adept user should be able to create simple experiments in Unity using the Toolbox. Previously, it would take some time to scroll through the code to find scripts and methods that are essential to create an experiment. There is now support for adding sounds to experiments and 3 experiment types: Change Blindness, Memory and newly added False Memory experiment. These experiments are ready to use by anyone. But creating anything outside that requires some knowledge about Unity game engine, which is not something most psychologists have time to acquire.

4.2 Future work

The Toolbox already has a wide range of capabilities, but there is always something to improve and improvements will probably be dictated by the demands of the users. However here are some ideas I would like to see implemented in the future.

Improving level creation. Currently the levels only have one setting which is a bunch of rooms, but what if the selected setting was a busy street? In that case the toolbox would not be of much use. Allowing for greater variety in level creation we allow more experiments to be conducted with the toolbox.

Adding Electroencephalography (EEG) support. Studies like “True or False? Physiological Measures May Answer the Question” have found great deal of information using electroencephalography. For example the mentioned study found that false memories exhibit greater arousal patterns compared to true memories [2].

Code should be refactored. Creating a new experiment took quite a while, because figuring out which parts of the scripts were absolutely necessary for the toolbox required some extensive digging. In the future it will be much easier thanks to the provided template. I

believe this should be done to every addition to the toolbox such as object change scripts, so that they can be added to future experiments with ease.

5. Conclusion

Current methods of studying false memory generally do not use realistic environments, instead preferring the use of language manipulation and fake photographs. All this due to the fact that creating environments for experiments in real world is very time consuming and costly endeavor. To provide a solution to this problem an experiment was added to Virtual Reality Experiments Toolbox to aid the research of the phenomenon.

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Appendix

I Code

Since the project is fairly large it is uploaded to Google Drive, the link allows access to the folder.

<https://drive.google.com/folderview?id=0B2uFhgEZhQpPREt3VTZUdEhoZXM&usp=sharing>

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