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THE EFFECT OF MUSIC ON MEMORY FOR FACTS LEARNED IN A VIRTUAL ENVIRONMENT

By

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Statement of Candidate

I certify that the work in this thesis entitled "**VirSchool – The Effect of Music on Memory for Facts learned in a Virtual Environment**" has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree to any other university or institution other than Macquarie University.

I also certify that the thesis is an original piece of research and it has been written by me. Any help and assistance that I have received in my research work and the preparation of the thesis itself have been appropriately acknowledged.

In addition, I certify that all information sources and literature used are indicated in the thesis. The research presented in this thesis was approved by Macquarie University Ethics Review Committee, reference number: **HE23FEB2007-D05027** on **09.03.2007**

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Fassbender E., Richards D., Thompson W. F., Bilgin A., & Taylor A. (2008, June 24 -27), The effect of Music on Learning in Virtual Environments - Initial Results Paper presented at International Conference on Auditory Display, Paris, France

Richards D., Fassbender E., Bilgin A., & Thompson W. F. (2008), An investigation of the role of background music in IVWs for learning. ALT-J, 16 (3), (pp. 231 - 244).

Fassbender E., Richards D., & Thompson W. F. (2007, December 5 to 7, 2007), How do Tempo and Pitch shifts of soundtracks for Roleplaying Games influence memory of facts conveyed in virtual-immersive environments? Paper presented at International Conference on Music Communication Science (ICoMCS), University of New South Wales, Sydney, Australia

Fassbender E., Richards D. (2008), Using a Dance Pad to Navigate through the Virtual Heritage Environment of Macquarie Lighthouse, Sydney. In T. G. Wyeld, S. Kenderdine & M. Docherty (Eds.), Virtual Systems and Multimedia (Vol. 4820, pp. 1-12). Berlin: Springer-Verlag.

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DEDICATION

For my family

I love you

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ABSTRACT

Video games are becoming increasingly popular and their level of sophistication comes close to that of professional movie productions. Educational institutions and corporations are beginning to use video games for teaching purposes, however, not much is known about the use and effectiveness of video games for such purposes. One even less explored factor in video games is the music that is played throughout the course of the games. Little is known about the role that this music plays in cognitive processes and what effect background music has on players' memory. It is this question that the present thesis explores by asking which effect background music has on participants' memory for facts that are learned from a virtual environment.

To answer the research question, a computer-animated history lesson, called VirSchool, was created which used the history of the Macquarie Lighthouse in Sydney as a basis for two experiments. Different musical stimuli accompanied the audio-visual presentation of the history topic. These stimuli were tested for their effectiveness to support participants' memory. The VirSchool history lesson was first presented in a Reality Center (a highly immersive, semi-cylindrical 3 projector display system) and one soundtrack was identified which showed a statistically significant improvement in the number of facts that participants remembered correctly from the VirSchool history lesson. Furthermore, Experiment 1 investigated how variations of tempo and pitch of the musical stimuli affected memory performance. It was found that slow tempo and low pitch were beneficial for remembrance of facts from the VirSchool history lesson.

The beneficial soundtrack that was identified in Experiment 1 was reduced in tempo and lowered in pitch and was subsequently used as the sole musical stimulus in Experiment 2. Furthermore, because of equipment failure,

Experiment 2 offered the opportunity to compare memory performance of participants in the Reality Center and a 3-monitor display system, which was used as a replacement for the defect Reality Center. Results showed that, against expectation, the memory for facts from the VirSchool history lesson was significantly better in the less immersive 3-monitor display system. Moreover, manipulated background music played in the second five and a half minutes of the VirSchool history lesson in the Reality Center resulted in a statistically significant improvement of participants' remembrance of facts from the second five and a half minutes of the VirSchool history lesson. The opposite effect was observed in the 3-monitor display system where participants remembered less information from the second five and a half minutes of the VirSchool history lesson if music was played in the second five and a half minutes of the VirSchool history lesson.

The results from the present study reveal that in some circumstances music has a significant influence on memory in a virtual environment and in others it does not. These findings contribute towards and encourage further investigation of our understanding of the role that music plays in virtual learning environments so that they may be utilised to advance learning of future generations of students.

1

INTRODUCTION

> *Enough has been said to show that music has a power of forming the character, and should therefore be introduced into the education of the young. The study is suited to the stage of youth, for young persons will not, if they can help, endure anything which is not sweetened by pleasure, and music has a natural sweetness. (Aristotle, 1885, p. 7)*

The above quote by Aristotle addresses a problem that has been paramount throughout the centuries and that we still see in present day society - Students of all ages avoid anything that is without a certain element of enjoyment or entertainment in it. Instead they are attracted by things that promise a quick reward or are seemingly more 'fun'. It is this fun, which is basically the modern word for pleasure, and attraction that is missing in many of the contemporary educational situations or as James Paul Gee puts it, "Educators often bemoan the fact that video games are compelling and school is not" (Gee, 2003, p. 68). The present study was motivated by the belief that *Virtual Environments* and *Music* could be the tools that make learning more fun and maybe could even improve learning.

1.1 Reality and Virtual Realities

We live in an era of rapid technological advancements. The recent developments in society and the influence of video games, virtual realities and virtual environments on everyday life are increasingly becoming part of our private and work environments (Zyda, 2005, pp. 25-32). In fact, "the lines between games and reality [are] continuing to blur" (Steere, 2008) and it is becoming increasingly difficult to distinguish between what is reality and what is virtual reality. This interconnectedness of natural world and virtual realities will grow the more improvements and developments are made in technology. With refrigerators connecting to the Internet[1] and neuro-headsets[2] in development, though in their infancy (Heingartner, 2009), that allow us to interact with computers through thoughts, it seems safe to predict that virtual environments and virtual realities will become increasingly ubiquitous in the future.

The most well-known incarnation of virtual environments are video games, be it on a personal computer, a video game console or a mobile phone. Already by looking at these three examples we can see that video games have been seamlessly integrated into our study rooms, living rooms and our pockets without us taking much notice. However, the more virtual environments become integrated into our daily routine the more we need to consider the role they play in our lives, their impact on the way we think and their potential for our personal and professional development. Shaffer states that while epistemic games (situated games that convey meaning, values and a defined way of thinking) are "not yet on the radar of most educators, they are already being used by corporations, the government, the military, and even by political groups to express ideas and teach facts, principles, and world views" (Shaffer *et al.*, 2005, p. 110). Shaffer continues his argument and states that if governments and corporations are investigating the potential of video games for training/teaching purposes "schools and school systems must soon follow suit or risk being swept aside" *(ibid)*.

In the next chapter we will look at the endeavours of the educational sector to do exactly this by developing so called serious games and we will look at various game genres of which the role-playing game genre seems to already use some effective methods to capture the audiences' attention. However, before

[1] http://www.whirlpool.com/content.jsp?sectionId=1205, last accessed: 09.02.2009

[2] http://emotiv.com/, last accessed: 09.02.2009

discussing the state of the video game industry, we will look at the reasons why this research was conducted.

1.2 Inspiration

The present study was inspired by a personal experience of the author in which he walked into a friend's room while his friend was playing a computer-based role-playing game. The author's friend was not playing the game like most other gamers on a standard desktop computer but instead with a technically sophisticated setup. The setup was comprised not only of a wireless keyboard and a wireless mouse, but also of a projection system that displayed the computer game on a 3 x 2.5 metres sized wall and a high-quality surround sound system. Except for the light that reflected from the display area there were no immediate light sources in the room and the author's friend was sitting on a couch with the wireless keyboard on his knees and the wireless mouse on the 25 cm wide, flat armrest of his couch. Upon entering this scene the author was first stunned by the amount of technology that had been put in place to create such an advanced gaming environment in an otherwise typical household. Shortly after the initial amazement wore off, the author realised the high level of atmospheric density of the situation. One factor for this atmospheric density, of course, was the extraordinary scale and quality of the display system. Other factors were the wireless keyboard and wireless mouse that had been put in place to eliminate distractions caused by cables. By taking away this element of distraction and making the usage of the interfaces as comfortable and integrated in the human-computer interaction as possible, the wireless keyboard and mouse became improved tools for seamless interaction with the computer game and the virtual alter ego in the game world.

However, the remaining factor that has not been discussed yet is the auditory environment. This auditory environment in computer role-playing games is quite often very finely crafted and similar in character to that of multi-million dollar blockbuster movies. Yet, it is quite often overlooked because of the dominance of the visual sense in both, movies and computer games.

The music and the sounds in the computer role-playing game that the author's friend was playing (World of Warcraft[3]) were ambient style fantasy themes which tend to have a mesmerising, almost hypnotic influence on the player. The author argues that it was this musical ambience that was the main reason why his friend was so captivated by the virtual environment before his eyes. His friend was so absorbed in the computer game that he did not even turn his head to greet the author entering the room. In this moment the author's friend was not playing the Battlemage displayed on the wall, he *was* the Battlemage.

1.3 Motivation

It has been argued that music is useful in creating (Järvinen, 2002, p. 119) and enhancing (Adams, 2002, p. 4) atmosphere in video games and the above experience demonstrates how engaging and engrossing the computer role-playing game was for the player. It is this atmosphere (also created by other elements apart from the music) that forms the very core of computer role-playing games and if a game succeeds to capture and hold the attention of the players, it has achieved its original aim, which is to entertain the players. It is this entertainment character of video games that is intended to be used for a virtual teaching environment.

[3] http://www.worldofwarcraft.com/, last accessed: 29.03.2009

Not only has Aristotle identified pleasure as a significant motivator for learning, but also Seymour Papert, a contemporary, world renowned educationalist, "remind[s] everyone that fun and passion are key ingredients of the learning process" (Papert, 2005, p. 6). Furthermore, San Diego based game designer Raph Koster states "basically, all games are edutainment" (Koster, 2005, p. 47) and connections are being made between motivation, video games and music and improvements in learning. For example, Judith Ramaley and Lee Zia report that "motivation is a key factor in the success or failure of education" (Ramaley *et al.*, 2005). Furthermore, Rita Weisskoff found that music motivated students to continue working on a language game task (Weisskoff, 1981) and Alice Mitchell and Carol Savill-Smith state that "Games [...] motivate via fun" (Mitchell *et al.*, 2004, p. 58).

All of the above researchers are experts in their field and they, together with educators millennia ago, all identify pleasure, fun and motivation as key factors for learning. Truly, if we want to engage the younger generation, we should re-think our teaching methods. If new technologies are available that offer a more compelling way of conveying information, teachers should make use of emerging technologies by inventing new ways to adapt the curriculum to a different way of learning. Thus, we as contemporary educators should investigate the power and possibilities of video games and music for teaching purposes. At the same time it is our duty to be careful and not jump completely onboard this 'brave new world ship', for our endeavours could be interpreted as leaving established teaching values and methods behind that were developed over hundreds of years of teaching tradition. We should keep in mind that even Socrates, despite being a keen educator, was sentenced to death for corrupting the youth with his revolutionary concepts. However, despite the danger of being called revolutionaries, it is our responsibility towards the next generations to evaluate which technologies are worth including into the teaching process and which are not.

1.4 Research Question

It was the subtle yet mesmerising power of the auditory environment in the situation of the author's friend playing the game that led the author to ask the research question about the effect that the music in games like World of Warcraft has on players' memory for facts that are conveyed in a game-like virtual environment. The reason for asking this question is that quite often the story that is built into these games is highly complex and foreign names and places have to be remembered in order to successfully complete a given quest. Thus, the question arises if the virtual environment and the music have any influence on how much players remember from this information. If it could be established that some types of music not only captivate players' attention and attract students to such environments but also improve their memory for the content that is being taught in them, an important argument would be added to the discussion of whether virtual environments and music should be integrated into the educational process of our children or not.

Therefore, to contribute to our understanding of the educational value of video games and music within our technologically advanced society, the two above variables were explored via the investigation of the research question:

> *How does background music affect human memory of facts that are conveyed in a virtual environment?*

1.5 Outline

In the present chapter the importance of fun for learning was discussed and the role that video games play in this area has been explained. Furthermore, the inspiration and motivation for this research project were described and the research question, which considers how music affects memory for facts that are conveyed in a virtual environment, was posed.

To answer the research question, a rigid research methodology was applied. The steps that make up the research method used in this thesis are described in the following four chapters.

Chapter Two highlights the literature that has been identified as being relevant to the present investigations and the hypothesis is presented as a result of the review of this existing literature.

In **Chapter Three** the development of a virtual history lesson about the history of the Macquarie Lighthouse is described. The relevant historical background is explained and the processes that were applied to develop the 'VirSchool', a computer-animated history lesson, are introduced. Furthermore, the research method used in this study is justified and described.

The VirSchool served as a framework for a series of experiments, which are described and analysed in **Chapter Four**.

Following the analysis of the experiments the results are discussed in **Chapter Five** and conclusions from the research project are drawn that lead to opportunities for future research.

2

Literature Review

Research into the effect of music on memory and learning in virtual environments is highly multidisciplinary with connections to Video Games, Virtual Environments and Music as well as Memory, Psychology, Learning and Teaching. The present study builds upon knowledge from all of these areas, however, the combined body of knowledge is vast and to cover all areas in their entirety would go beyond the scope of this thesis. The thesis is thus restricted primarily on work that considers memory, music, video games and virtual environments with particular interest in work spanning all four or multiple of these areas. In this chapter we will describe the findings, which considered together, form the background for the VirSchool project. The knowledge gained from the literature of the related fields forms the basis for the hypothesis, which is stated at the end of this chapter. We will explain some basic principles of human memory, one aspect that is required for learning, before discussing virtual environments and video games and how some of these virtual environments and games are used for learning purposes. Next we will talk about music and its effect on memory in a variety of situations. But before we can get to this, we have to understand how our memory works.

2.1 Human Memory

Memory is an important human feature and it is memory that makes us unique individuals. It is our "ability to recall events, ideas, and feelings from [our] past [that] is one of the distinguishing characteristics of humans" (Benner *et al.*, 1999, p. 737). Researchers continuously investigate the functioning of the brain to understand how memory works and without the memory for past events (e.g. caused by amnesia through accidents) humans often struggle with their identity because they do not know who they are any more. For example, Lucchelli *et al.* (1995) report a case of memory loss through stroke where an artist named GR woke up one morning and could not move his right arm nor did he remember his past. In the following weeks he suffered severely from this memory loss and "GR felt deeply depressed, hopeless, about his amnesia to the point that he could not find the inspiration to paint again" (Lucchelli *et al.*, 1995, p. 170). But not only does memory form a very important part of our identity, it is also a fundamental element for learning. The ability of the human brain to remember information and events makes it a crucial part of our research. In the next sections we will explain the principles that have been established about how the human memory works and how it can be supported to remember certain things.

The Macquarie Dictionary defines memory as "the mental capacity or faculty of retaining and reviving impressions, or of recalling or recognising previous experiences" and "the act or fact of retaining mental impressions; remembrance; recollection" (Delbridge, 1997, p. 1343). Another definition is that memory is "The psychological function of preserving information, involving the processes of encoding, storage and retrieval" (Colman, 2003, p. 438) and there are numerous further definitions of memory. One thing they all have in common is that they explain the ability of our brain to store events and information in order to recall them at will at a later time.

In order to learn and understand something, learners have to relate new information to information that is already existing in their memory storage (Sweller, 2003). Furthermore, there is a difference between how experts and novices process information (Bransford, 2000 p. 31). Bransford explains that experts (e.g. chess masters) 'chunk' information into categories so that they can access and process this information at a later stage together with new information without overloading the capacity of the working memory. As deGroot (1965) found in his seminal work into the differences between chess experts and novices, memorisation of *facts* is not a distinguishing feature between the experts and novices, rather it is the way that the facts are organised (see further discussion in the section on storage and long term memory). We acknowledge that the measurement of remembered facts in this thesis does not address higher-order learning but rather investigates rote memorisation of facts. However, given the sparseness of studies concerning music, memory and virtual environments, we have restricted our attention to this less complex learning activity of rote memorisation of facts.

As indicated by Colman (2003), memory can be separated into three aspects - the *encoding* of information, the *storage* of this information and the *retrieval* of the information from memory. However, since our study measures the memorisation of facts, we restrict our consideration to the encoding and to a lesser extent the storage process of the brain. For completeness, a brief description of retrieval (and forgetting, a fourth aspect that is rarely mentioned) has been provided in Appendix A.

Encoding

According to Weiten (1992), attention is crucial for encoding information into our memory. He explains that memory is largely an active process and that we are unlikely to remember something unless we make a conscious effort to do so (Weiten, 1992, p. 233). Furthermore, Weiten explains that by attention he means that we deliberately filter all the incoming information and focus on one stimulus. In the same regard, Vester (1975) argues, together with others (Aristotle, 1885; Koster, 2005; Mitchell *et al.*, 2004; Papert, 2005; Ramaley *et al.*, 2005; Weisskoff, 1981) that motivation is one of the key factors for the intake of new information. Others (Dryden *et al.*, 2001), suggest that knowledge is best anchored if several input channels are offered. The more senses used to mediate information, the better.

Our senses (sight, hearing, touch, taste, smell) are the first point of contact for any information coming from the external world into our internal memory system. *Sensory memory* plays an important part in this process, as it is the physical memory of our senses that preserves the incoming information in its original form for a very short time. For our eyes this is approximately 0.25 seconds (Weiten, 1992, p. 239) and one can observe this effect when looking at fire twirlers at night - the circles that their burning sticks and cups produce is due to the latency of our eyes in processing the information. On the aural side Dix *et al.* (1998, p. 27) explain sensory memory by an example of a friend approaching and asking us a question while we are deeply concentrating on something else. Initially we might not hear the question completely because our attention is focused on another task, but when we ask the friend to repeat his or her question, we are very likely to know roughly what he or she is going to tell us. Our sensory memory preserves the information for a certain amount of time and then passes it on to the next stage in the memory process - our short-term memory.

Short-term memory is also called working memory (Dix et al., 1998; Weiten, 1992) and keeps the information that is coming from the sensory memory available for further processing (see Appendix A for the amount of time that information is kept in short-term memory). In order to filter out important or desired information from all the competing incoming stimuli, we need to make a conscious effort to focus on the one thing that we want to learn. We have to block out all other stimuli in order to be able to concentrate on the information that we want to imprint into our memory (see Appendix A for the amount of stimuli that reaches us per second and how these stimuli are filtered to avoid information overload). At this point it should be mentioned that information overload is a problem that has been investigated by Miller (1956) and more recently by Sweller (1988). Cognitive overload basically describes the limited capacity of the human brain to keep five to nine pieces of information in working memory.

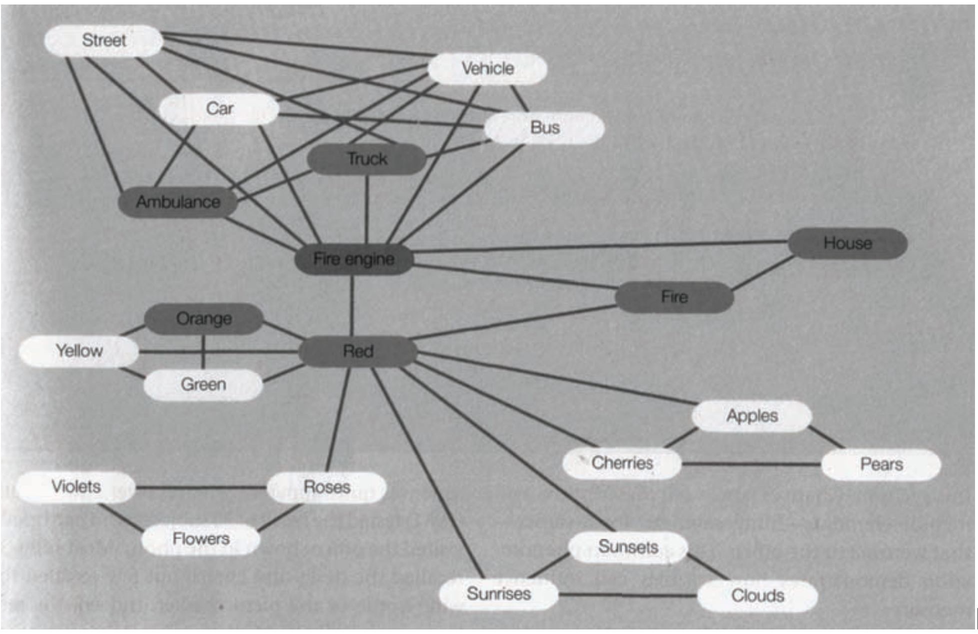
Because of its relevance at another point, cognitive overload is included in the discussion section (4.2.6) of Experiment 2. Information, that has not been lost because of cognitive overload and that has instead been kept long enough in working memory, by attention and/or motivation, is then passed on to long-term memory.

Storage

Long-term memory is the knowledge space where information is filed for later recall. It is "an unlimited capacity store that can hold information over lengthy periods of time" (Weiten, 1995, p. 292). Long-term memory is either organised in a conceptual, hierarchical system or in a semantic network (Weiten, 1995, p. 265). The following explanation of the conceptual, hierarchical system and the semantic network is combined from Weiten (1992) and Dix *et al.* (1998).

For the *conceptual, hierarchical system* clusters of information are formed which file certain types of information in one group. An example of such a hierarchical system is the biological classification of species and organisms into the five kingdoms - plants, bacteria, fungi, animals and algae. Every species on our planet can be categorised into these five generic classes and the lower levels categorise sub-classifications for each species. This structure allows us to access information by thinking of the generic term first and then continue deeper into the hierarchy to remember more specific details.

Semantic networks are a further storage strategy of our brain that is different from the hierarchical model because semantic networks allow single pieces of information to be linked across classification levels. Furthermore, the importance of the information is weighted, meaning that information that is closer to the generic term is easier to access and information further away (more loosely connected) is harder to access. If we take for example the 'Fire engine'


Street
Vehicle
Car
Bus
Truck
Ambulance
Fire engine
House
Fire
Orange
Yellow
Red
Green
Apples
Cherries
Pears
Violets
Roses
Flowers
Sunsets
Sunrises
Clouds

learning, then play and playing games are worthy of consideration as teaching instruments. In the next two sections we will therefore look closer at these two aspects when we discuss virtual environments and video games.

2.2 Virtual Environments

The term Virtual Environment (VE) is often used for both, Virtual Reality (VR) and Virtual World (VW) (Sherman *et al.*, 2003, p. 16) where the latter is in fact almost the same as VE. However, VE is the older term that was already in use in the mid-1980's by researchers at NASA's Ames Research Lab to describe an interface that allowed a user the experience of a computer-generated scene from a first-person perspective (*ibid.*). Thus, the term virtual environment describes a virtual world that is displayed as a virtual reality.

The term Virtual Reality itself, however, is often misused, due to the reason that VR is a new form of media and its definition "is still in flux" (Sherman *et al.*, 2003, p. 6). Having said that, the term VR generally describes a collection of hardware, software and content that allows a user a virtual reality experience. The definition used by Sherman *et al.* (*ibid.*) indicates four key elements that have to be present to warrant the term Virtual Reality:

- Virtual World – There has to be content for the Virtual Reality
- Immersion – The users have to be immersed into an alternate reality or point of view
- Sensory Feedback – The VR system provides direct sensory feedback to the participants based on their physical location (e.g. adaptation of the visual scene based on head movement)
- Interactivity – For an authentic presentation of a Virtual Reality, the Virtual Reality should respond to user actions

The test scenario created for the experiments of the present thesis (see section 3.3.1) would fall into the above category of a virtual world that is displayed in a virtual reality, however, because the scenario used in this thesis is lacking sensory feedback and interactivity we clearly want to distinguish it from the above definition of VR. Therefore, because of the ambiguity that exists about the term VR it seems appropriate to use the term Virtual Environment, which is a more general term and "often used as a synonym for both Virtual Reality and Virtual World" (Sherman *et al.*, 2003, p. 16). The term Virtual Environment thus offers more room for interpretation and acts as an umbrella term. In this thesis it is being used in this more common way and refers to a 3D-animated, immersive, computer-generated virtual world, including video games (which, according to the above classification criteria, would almost qualify as a VR except that they are lacking 'sensory feedback').

Similar to the ambiguity about the terms Virtual Reality and Virtual Environment, there is an ongoing discussion about the term immersion (Mania *et al.*, 2001; Slater *et al.*, 1997; Witmer *et al.*, 1998). It is not easy to define what is 'immersive' in VR research and what is not. While the effect of immersion on learning is not the major research aim of the present study there is considerable interest and debate regarding the measurement and effects of immersion (e.g. Brown and Cairns, 2004; Jennett et al. 2008; Seah and Cairns, 2008) and presence on learning (e.g. Moreno & Mayer, 2004). While Slater (2002) clearly indicates that "the higher the degree of immersion [...] the greater the degree of presence" (p. 24) and Mikropoulos (2006) reports that "in general, the pupils had a high sense of presence interacting with our EVE [Educational Virtual Environment] and this helped them perform their learning tasks successfully" (p. 205), the link from an increased degree of presence to improved learning has not been confirmed by others (Moreno *et al.*, 2002, Persky *et al.*, 2009). Even a good book or cinema experience can be termed immersive (Slater *et al.*, 2002, p. 18) or a static Van Gogh painting "gives a strong impression of movement" (Slater *et al.*, 2002, p. 13). Thus it seems appropriate to also define the use of the term immersion within this thesis. Immersion in the present context means that participants are captivated by the virtual environment to a degree where they lose track of time. This variable has been measured with a number of questions in the questionnaires (see section C in Appendix C) of associated experiments. Now that we have defined how the terms VE and immersion are to be understood in this thesis, we will describe some of the many uses for virtual environments.

The variety of different display methods for VE's ranges from desktop monitor display systems, head-mounted displays (HMD), wall projection technology, Reality Center™ (SGI, 2009), CAVE™ (Cave Automated Virtual Environment) display systems (Cruz-Neira *et al.*, 1993) to Augmented Reality (virtual environments superimposed on real-world surroundings with e.g. special glasses). Applications of virtual environments include command training of fire-fighters (St. Julien *et al.*, 2003), safety training for mine workers (UNSW, 2008) and pilot training (Dörr *et al.*, 2000). Furthermore, virtual environments are used to teach Medicine (Lu *et al.*, 2005) and collaborative haptic surgical training over the Internet (CSIRO, 2007). Virtual environments have created high interest for their training potential because they enable much cheaper training than for example traditional flight training in a physical real-world simulator (Dörr *et al.*, 2000, pp. 11-11). Furthermore, virtual environments are used to treat social phobia (Klinger *et al.*, 2005), for rehabilitation of brain injury/damage (Rose *et al.*, 2005), training for patients with schizophrenia (Ku *et al.*, 2007) and their feasibility for treatment of persecutory delusions (Fornells-Ambrojo *et al.*, 2008).

Recently, applications have emerged that are accessible by multiple users from different areas of the globe who interact with each other simultaneously over a network (e.g. the Internet). These virtual worlds are called multi-user virtual environments (MUVEs) and developed out of multi-user dungeons (MUDs), an earlier text-based version of massively multiplayer online role-playing games. Some prominent examples of MUVEs are Second Life[4], Croquet[5], Quest Atlantis[6] and Active Worlds[7]. All of these MUVEs feature a 3D virtual environment and offer users the opportunity to communicate in a 3D environment in real-time. Where Second Life has different worlds on offer (e.g. an adult Second Life and a Teen Second Life), Quest Atlantis (see Figure 2) specifically focuses on combining a video game environment with knowledge from educational research on learning and motivation. Quest Atlantis allows students to interact with teachers and peers and make informed decisions about certain quests. One such quest requires students to make decisions about what to do to stop the depletion of fish in an aquatic reserve of a national park (e.g. stopping indigenous people from farming, stopping loggers from cutting trees or shutting down a game fishing company). Players then have the opportunity to travel forward in time and see how their decisions affected the ecosystem. Students are then asked to reflect on their decisions and experiences. Figure 2 shows the user interface of Quest Atlantis with the 3D world displayed in the main window (left) and a chat section displayed underneath where participants can communicate with each other. On the right hand side the user interface offers a section for additional information and user notes.

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[4] http://secondlife.com/, last accessed: 18.08.2009

[5] http://croquetconsortium.org/index.php/Main_Page, last accessed: 18.08.2009

[6] http://atlantis.crlt.indiana.edu/, last accessed: 18.08.2009

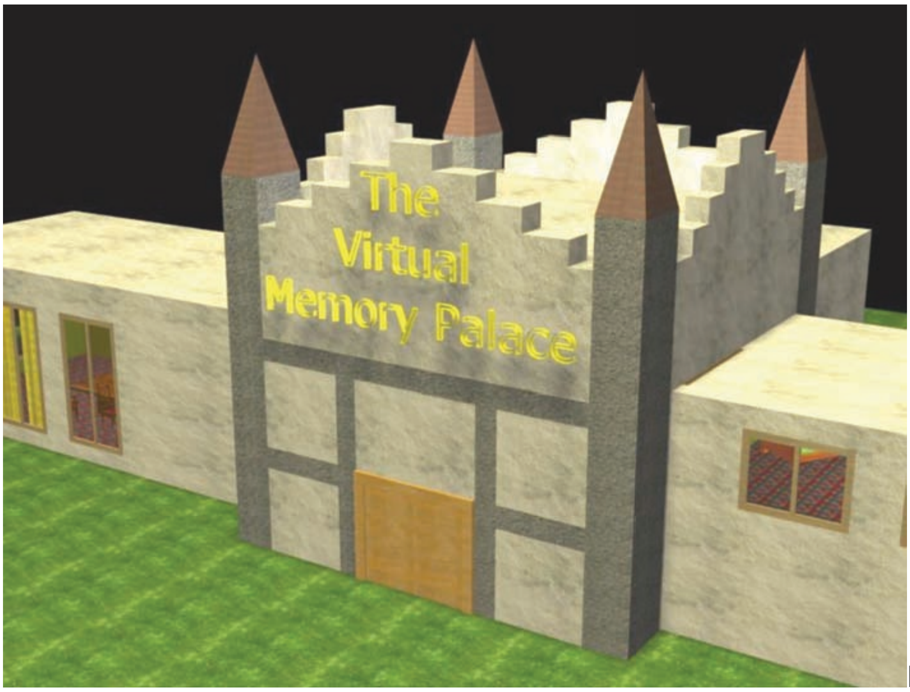
[7] http://www.activeworlds.com/, last accessed: 18.08.2009

Figure 2: A scene from Quest Atlantis with the main window left, the chat area below and space for additional information and personal note taking on the right.

Another MUVE with educational background is the 'River City' project[8] at Harvard University. In River City students travel back in time to the 19th century in order to help residents in a town with health problems. Students work in small research teams to find out the reasons for the illnesses. They use in-game technology to keep track of their various findings and then pose hypotheses as to why residents fall ill. Based on this information students can develop controlled experiments to investigate if their hypotheses for the causes of the illnesses were correct. The project Virtual Singapura (Jacobson *et al.*, 2008) has a similar topic with students going back in time to help the 19th century Governor of Singapore, Sir Andrew Clarke, to figure out the causes for a disease epidemic that spread in that time period.

[8] http://muve.gse.harvard.edu/rivercityproject/ , last accessed: 18.08.2009

One example that is particularly relevant to the present study because it investigated the effectiveness of a virtual environment to support memory is the *Virtual Memory Palace* (Fassbender *et al.*, 2006). The Virtual Memory Palace is a virtual representation of traditional Memory Palaces invented by the ancient Greeks who used architectural models to associate information to certain points (so called loci) of these structures and thus allowed the memorisation of the associated information. The original Memory Palaces have been popular in their own time, in the Middle Ages and the Renaissance (Yates, 1966) but unfortunately the memory technique has been buried over the centuries and was almost forgotten. The Virtual Memory Palace (see Figure 3) seeks to revive this memory technique and allows users to associate pictures to certain locations in a 3-dimensional (3D) building to improve users' memory for items they wish to remember. The results of an accompanying experiment showed that one week after initial experiments participants remembered 28.4% more of the items that were placed in the Virtual Memory Palace as compared to items from a word list. The Virtual Memory Palace was an honours project (i.e. a fourth year undergraduate research project) and statistical analysis was limited, however, the results were encouraging and support the claim that visually supported learning techniques are beneficial for memory improvements.


The
Virtual
Memory Palace

2.3 Play, Games and Video Games

> *The spirit of playful competition is, as a social impulse, older than culture itself and pervades all life like a veritable ferment. Ritual grew up in sacred play; poetry was born in play and nourished on play; music and dancing were pure play. Wisdom and philosophy found expression in words and forms derived from religious contests. The rules of warfare, the conventions of noble living were built up on play-patterns. We have to conclude, therefore, that civilization is, in its earliest phases, played. It does not form play like a babe detaching itself from the womb: it arises in and as play, and never leaves it. (Huizinga, 1949, p. 172)*

Most people have played games in one form or another at some stage of their lives and many people consider play as essential for recreational activities. One of the questions that arises from this phenomenon is what the reasons for this play are? Johan Huizinga, one of the pioneers on the concept of play (Anchor, 1978, p. 63), describes play as a voluntary activity (Huizinga, 1949, p. 7) and as "standing outside ordinary life" *(ibid. p. 13).* Inferring from his quote at the beginning of this section and throughout his book, Huizinga goes even further and states, "pure play is one of the bases of civilisation" *(ibid. p. 5)*. He continues to argue that play is "absorbing the player intensely and utterly" *(ibid. p. 13)* and has rules and order *(ibid. p. 10)*. Furthermore, there is no material interest involved in play and yet "play does not exclude seriousness" *(ibid. p. 180)*. Play is the main element commonly shared by video games and games in general.

There is a slight difference between computer games and video games in that computer games are mostly developed and distributed on personal computers (like PC's and Macintosh computers) and video games have a focus on video consoles (like the Xbox360[9], Playstation 3[10], Nintendo Wii[11]). Despite this difference, the two categories of games are commonly combined into one category (ESA, 2008). The term video games is also used as an umbrella term for other genres (arcade games, games played on mobile phones, etc.) and for every game played on an electronically supported display device. Following the example of Zehnder and Lipscomb (2006, p. 241) and because the overall characteristics of computer and video games are very similar in relevance to the present study, the two terms are used interchangeably within the remainder of this thesis.

As Apperley (2006) points out, video games are a rather young media form and thus the classification of video games into different genres is not only still in its infancy but also often wrongly mingled with classifications of movies. Wolf (2001) set out to categorise video games into 42 different genres based on the 'Moving Image Genre Form Guide' by the Library of Congress[12], however, for reasons of practicality we consider only the "more popular genres" (Apperley, 2006, p. 8) of Simulation (2.3.1), Strategy (2.3.2), Action (2.3.3), Role-Playing games (2.3.5) and add serious games (2.3.4). We focus on the latter two because of their relevance to this study.

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[9] http://www.xbox.com/, last accessed: 29.03.2009

[10] http://www.us.playstation.com/, last accessed: 29.03.2009

[11] http://wii.nintendo.com/, last accessed: 29.03.2009

[12] http://www.loc.gov/rr/mopic/miggen.html, last accessed, 30.07.2009

In the following sections we will look at video games from various angles. First we will introduce the different video game genres before talking about serious games, role-playing games and the benefits of *playing* games. We will then show how video games are used for teaching purposes before discussing the criticism that is often used against video games. We will then see how even the critics' negative view has a positive side to it.

2.3.1 Simulation Games

Simulation video games include sport, flying, management, life and training simulations that allow players to imitate or trial certain activities in an environment that is modeled to be a computer generated representation of a realistic situation. Thus, they offer players the opportunity to explore different actions and observe the outcomes of their choices. Typical examples are Microsoft Flight Simulator[13], the Sims[14], Police Trainer[15] and Pro Evolution Soccer[16].

2.3.2 Strategy Games

Strategy games are commonly games of warfare in which players explore an area, exploit its resources and attack an enemy or defend themselves from attacks. Similar to simulation video games players can try different tactics and see the outcomes of their actions. However, unlike simulations, strategy games

[13] http://www.microsoft.com/games/flightsimulatorx/, last accessed, 30.07.2009

[14] http://thesims.ea.com/ last accessed, 30.07.2009

[15] http://www.allgame.com/game.php?id=14025, last accessed, 30.07.2009

[16] http://www.konami.com/games/pes09/, last accessed, 30.07.2009

can have their own rule system that is not necessarily based on real life situations. Strategy games can be turn-based strategy (i.e. one player makes a move, finishes his turn and waits for the opponent or collaborator to make his/her move; e.g. The Battle for Wesnoth[17]) or real-time strategy (i.e. all players make continuous moves and the game progresses without a waiting period; e.g. Age of Empires II[18]).

2.3.3 Action Games

Action games have many sub genres but they can basically be separated into first-person and third-person action games. In a first person action game players look at a scene as if they were inside the head of the player character, whereas in third-person view games the playable virtual character (often called Avatar) is displayed partially or fully on the screen. Players look at the Avatars rather than seeing the virtual world through the eyes of the Avatars as in first person action games. Action games require fast reflexes and usually have a rather simple objective, which includes fighting other characters in a quick succession of attacks. Typical action games are Street Fighter[19], Pitfall[20] and Tomb Raider[21]. First person 'shooter' games (e.g. Doom[22], Counterstrike[23]) also fall into this category of video games.

[17] http://www.wesnoth.org/, last accessed, 30.07.2009

[18] http://www.microsoft.com/games/age2/, last accessed, 30.07.2009

[19] http://www.streetfighter.com/, last accessed, 30.07.2009

[20] http://www.allgame.com/search.php?game=Pitfall!, last accessed, 30.07.2009

[21] http://www.tombraider.com, last accessed, 30.07.2009

[22] http://www.idsoftware.com/games/doom/doom3, last accessed, 30.07.2009

[23] http://store.steampowered.com/app/240/, last accessed, 30.07.2009

These examples give only a small insight into the broad variety of computer and video games and the beneficial features might not be visible at first glance. However, in so-called serious games educational aspects are the main objective of the game and thus more obvious to the eye of the beholder.

2.3.4 Serious Games and Edutainment

Similar to the educational MUVEs mentioned earlier, the objective of 'serious games' is to communicate and teach real-world issues through the use of video game technology. Serious games often have a political background like *Global Conflict: Palestine*[24], *Darfur is Dying*[25] and many more[26]. In Global Conflict: Palestine, for example, the players learn about the conflict between Israel and Palestine while taking on the role of a journalist. Darfur is Dying has a similarly serious topic where users learn about the background of the genocide in Darfur. Where these two games mainly aim to educate mature players about political issues in particular regions of the earth, another genre of games focuses more on educating children while being entertaining at the same time. These educational games with entertainment qualities are called 'Edutainment' games, which is a combination of the terms *Edu*cation and Enter*tainment*. Edutainment games quite often cover educational (e.g. Where in the World is Carmen San Diego[27]) or health topics (e.g. Re-Mission[28]). Edutainment is, however, often criticized as "sugar coating" (Prensky, 2001a, p. 379) the serious topics, where it should be clarified that Prensky clearly distances himself from such a statement.

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[24] http://www.globalconflicts.eu/, last accessed: 09.02.2009

[25] http://www.darfurisdying.com/, last accessed: 09.02.2009

[26] http://seriousgamessource.com/, last accessed: 09.02.2009

[27] http://www.carmensandiego.com/

[28] http://www.re-mission.net/

In this context it seems appropriate to not only refer to the examples that Prensky gives for meaningful Edutainment (Prensky, 2001a, p. 381) but also to cite Huizinga again who says that play does not exclude seriousness (Huizinga, 1949, p. 180). In this light and keeping the Aristotelian statement in mind that teenagers only pursue things that involve a certain element of pleasure, many educators are currently turning their attention to the use of video games for teaching purposes (Prensky, 2001b).

However, there is one major difference between mainstream and serious video games, which prevent serious games from 'breaking through'. This difference is the budget that is spent on game development. While the development of a top mainstream title can cost up to 100 million US dollars (Grand Theft Auto IV)[29], 'serious games' are often sponsored by charities or not-for-profit organisations which have significantly smaller budgets for the development of their games (Egenfeldt-Nielsen, 2006). Furthermore, due to the business environment, mainstream video game producers have access to the top developers in the video game industry while for some of the serious games producers it is their first attempt at developing a game. They often deal with smaller development companies that do not have the resources to hire the top video game programmers. For these reasons the quality of serious games often lags behind that of mainstream titles and none of the serious games are ranked in any of the lists of top selling games[30]. This is especially disappointing because serious games (arguably) have the more interesting and valuable content. There is still a wide gap to be bridged between traditional educational methods found in most of today's schools and the acceptance of (serious) games for teaching purposes.

[29] http://blog.knowyourmoney.co.uk/index.php/2008/08/10-most-expensive-video-game-budgets-ever/

[30] e.g. http://videoonlinegames.suite101.com/article.cfm/may_2008_video_game_sales_charts

In order to help to create more awareness of the good educational games that are being developed, we want to mention a few such examples.

One very good example for entertaining games with an educational background is the game *The Secret of the Lost Cavern*[31] which is set in the Palaeolithic stone age period 15.000 years B.C. In this game the player assumes the role of a young pre-historic tribesman (the play character is a young male) who follows the path of a renowned cave painter of his time period. On his journey the player has to solve puzzles and learn the art of cave painting. The Secret of the Lost Cavern has a high educational value because it is built upon scientific facts and it contains a database that can be referenced by the player throughout the game to lookup information relevant to a current task. For example, the players can lookup how pre-historic men made fire in order to make fire themselves in a game situation where fire is needed to light a dark cave.

Another good example of how video games and learning can be successfully combined is the video game *The Monkey Wrench Conspiracy*[32] that was designed and developed to introduce Computer Aided Design (CAD) engineers to use a particular CAD software. The product entered the market as a competitor to the market leader at the time of its introduction. In this educational video game, the engineers had to protect a space station and prevent an evil enemy (Doctor Monkey Wrench) from blowing up half the galaxy. In one part of the game the engineers had to construct a trigger for a weapon by using the company's CAD program. In this way the target group learned to use the new CAD program through playing a computer game instead of reading a technical manual. It turned out that the approach of training people in the usage of a new software through a computer game was highly successful and a year after the initial

[31] http://www.lostcavern.com/, Last accessed: 17.12.2008

[32] http://www.games2train.com/site/html/tutor.html, Last accessed: 17.12.2008

release of the training game close to a million copies of the game were in print (Prensky, 2001a, p. 26).

A game that shows how experiences gained in video games may translate into the real world is the upcoming game 'Emergency Room: Real Life Rescues' by Legacy Games[33]. Here players can treat cardiac arrest, broken bones and life-threatening traumas where "mini-games and realistic medical content provide a perfect balance of fun gameplay and authenticity" (Legacy-Games, 2009). The key point in this case is that players can inform themselves at a very young age about the medical profession in a game environment. Furthermore, it is a perfectly safe environment where they can practice different treatments repeatedly and without serious consequences. Players can learn something meaningful that is according to their interests and possibly helpful in forming their study and career aspirations. Play has always served that function and with authentic games, players may be able to make more informed choices. Even those who are not interested in pursuing a career in the described area will learn more about how the body works which can be beneficial to their own wellbeing.

A further example for an educational, serious game with entertainment influences is the game *Re-Mission* of the Hopelab non-profit organisation[34]. Here users have to fight cancer cells in order to help a virtual patient get better or do his/her breathing exercises (see Figure 4). The game consists of various missions in which the patients learn about microscopic cancer cells that replicate in the body. The players take control of Roxxi, a nanobot that has to be guided through the complex environment of the human body. On her way Roxxi fights the cancer cells with weapons such as the 'Chemo Blaster' and the 'Antibiotic Rocket' and the game is based on scientifically accurate information that educates children

[33] http://www.legacygames.com/, last acccessed: 27.07.2009

[34] Hopelab: http://www.hopelab.org/, last accessed: 10.12.2008

bpm
80
1
454

because of the music that is played in most games of this genre. The reasoning for the choice of music will be further explained in section 3.3.2. The next section focuses on RPG's and the learning aspects in some exemplary games.

2.3.5 Role-Playing Games

There are two types of role-playing games (RPG), multi-player and single-player, which offer players the possibility to take on certain roles, as the name implies. The players decide which skills they want their virtual alter egos to improve and in which direction they want their characters to develop. In this context it should be pointed out that the term 'characters' in the previous sentence can be interpreted as 'the characters that users are playing inside a game' or 'their personal real-life characters'. This double meaning is intended because it is argued that by learning how to develop a computer game character, players also learn to develop their personal real-life character.

The networked versions of such computer RPGs are called *Massively Multiplayer Online Role Playing Games* (MMORPG), which include *World of Warcraft*[35], *Lineage 2*[36] and *Age of Conan*[37]. These MMORPG attract, as the name suggests, a truly massive number of players from around the globe and are played over the Internet. As an example of the number of players that play these games, it should be mentioned that in 2008 in its fourth year, World of Warcraft *alone* brought together 11 million computer gamers (Fahey, 2008) from almost every corner of the world. This is an enormous number of people who are playing in the same virtual environment.

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[35] http://www.worldofwarcraft.com/, last accessed: 18.12.2008

[36] http://www.lineage2.com/, last accessed: 18.12.2008

[37] http://www.ageofconan.com/, last accessed: 18.12.2008

Apart from Massively Multiplayer Online Role Playing Games there are *Single Player Role Playing Games* like *The Elder Scrolls IV – Oblivion*[38], *Ultima*[39] and *Dungeon Siege*[40] which, although not attracting quite as many players (e.g. The Elder Scrolls IV – Oblivion, 3 million copies for Xbox 360 and PC in 2006, (Brenn, 2007)) as their MMORPG equivalents, are similar in terms of visual and auditory quality. This variant of role-playing games also features the (virtual) character development and a particularly good example of such "practice for a real-life challenge" (Koster, 2005, p. 53) can be found in The Elder Scrolls IV - Oblivion.

In this game the player has the choice of joining different 'guilds' – for example, the Fighters Guild, the Thieves Guild and the Mages Guild. In each of these guilds the player has to fulfil certain tasks in order to move up in the hierarchy and reach the next rank. If, for example, the player chooses to join the Mages Guild, at some point he or she is required to collect reference letters from four mages who live in different parts of the (video game) country. Once the player has successfully collected these reference letters, he or she is admitted into the library of the mages guild to further his or her knowledge. The lesson that players of this particular quest might learn and transfer into a real-life scenario is that reference letters might help them with job applications at another stage of their lives.

Another example of skill transfer from a video game into a real-life situation is the report[41] of a man in North Carolina who saved two injured passengers from a crashed car and treated their wounds based on skills that he claims he learned while playing a paramedic in the computer game America's Army. While

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[38] http://www.elderscrolls.com/home/home.php, last accessed: 18.12.2008

[39] http://www.uo.com/archive/, last accessed: 18.12.2008

[40] http://www.microsoft.com/games/dungeonsiege/, last accessed: 18.12.2008

[41] http://www.wired.com/gamelife/2008/01/americas-army-t/, last accessed: 18.08.2009

America's Army[42] is technically a 'First Person Shooter' action game rather than a role-playing game, the connection between skills learned in the game and application of these skills in the real world becomes clear. It should, however, be noted that such claims may sometimes be exaggerated.

A more rigid investigation was conducted by Gee (2003), who explored how players learn to form an identity through video games and how they are given the choice of trying different strategies towards solving a given problem. Gee suggests that the opportunity to chose different strategies not only motivates users to learn and play the game but also encourages users to reflect on their learning and problem solving styles (Gee, 2003, p. 81). Gee further claims that "in video games, we play with life as if life were a toy" (Gee, 2008, p. 261) and he recently focuses on embodiment in video games. He suggests that players use video games, like the aforementioned RPG's, to take on specific identities in order to try out what it would be like to be a certain persona. In order to do this, players have to "become" the virtual character they inhabit. They have to see the (virtual) world through the characters' eyes keeping its needs and goals in mind. Furthermore, Gee says that every project that we take on (in the real or virtual world) is a dynamic process and that we constantly have to adapt such a project to changed circumstances. Video games allow us to make mistakes and try again without the negative consequences some decisions would have in the real world (Gee, 2008). Gee's concept of embodiment has, in fact, been formulated 70 years ago[43] by Huizinga who has looked at play not only from a societal viewpoint but also from a ritualistic and religious perspective. He states

[42] http://www.americasarmy.com/, last accessed: 18.08.2009

[43] The original book and idea were published in 1938, however, we are refering to an edition published in 1949. Hence the time period indicated in the text may vary by 9 years.

> *So that the apparently quite simple question of what play really is, leads us deep into the problem of the nature and origin of religious concepts. As we all know, one of the most important basic ideas with which every student of comparative religion has to acquaint himself is the following. When a certain form of religion accepts a sacred identity between two things of a different order, say a human being and an animal, this relationship is not adequately expressed by calling it a "symbolical correspondence" as* ***we*** *perceive this. The identity, the essential oneness of the two goes far deeper than the correspondence between a substance and its symbolic image. It is a mystic unity. The one has* ***become*** *the other. In his magic dance the savage* ***is*** *a kangaroo. (Huizinga, 1949, p. 25)*

Again, in this example of an indigenous person impersonating an animal, we see the state of complete absorbedness that is a major aspect of play, expression and learning. When we look at video game players, we find that quite often they are also completely occupied by the games they are playing. In the example of the author's friend playing World of Warcraft (outlined in the Introduction chapter), the players' attention was so intensely focused on the fantasy world in which he was roaming about, that almost nothing could disturb him and get him out of the fantasy world and back into reality.

One explanation for this deep engagement could be Csikszentmihalyi's 'Flow' theory which describes "the state in which people are so involved in an activity that nothing else seems to matter" (Csikszentmihalyi, 1990, p. 4). Another explanation could be that "video game play is an activity which lies in the domain of intrinsic motivation" (Holt, 2000, p. 9). Habgood *et al.* (2005) state that feelings of total concentration, distorted sense of time, and extension of self are experiences that are as common to game players as they are to rock climbers and surgeons who have to fully concentrate on their tasks (Habgood *et al.*, 2005, p. 492). Habgood *et al.* also investigated the flow experience from a different angle and refer to "a number of studies that associate the symptoms of flow with the negative effects of addiction" *(ibid. p. 492)*. They claim that "yet, it is these kinds of experiences [feelings of total concentration, distorted sense of time, and extension of self] that seem to be at the very root of the engagement power of digital games" (*ibid. p. 492*). Therefore, if players become absorbed in a video game they inhabit the role of an Avatar (virtual in-game persona) and explore what it is like to be a particular character. The experiences gathered while playing a certain role may then translate into real-life situations. For example, if an Avatar jumps and runs throughout the virtual game world, its acrobatic skills increase and after a couple of hours of such training, the Avatar is rewarded with endurance points which allow it to jump higher or run for an extended period of time without getting out of breath. As we can see from this example, the game situation resembles a real-world situation very closely and players may translate the information into real life and understand that if they would do the same thing (jumping and running) in real life, they would soon see a similar outcome as in the video game environment. The more they train, the better their physical abilities become.

2.3.6 Benefits of playing Video Games

There are many non-violent video game genres that focus on adventure (e.g. Kings Quest), music (e.g. Guitar Hero), sports (e.g. Colin McRae Rally), logical thinking (e.g. Sudoku, Chess, Brain Age), puzzle solving (e.g. Zoombinis), jump-and-run (e.g. Super Mario Bros) and educators realise that the possibilities of such non-violent (serious) video games could outweigh the dangers (see Criticisms in section 2.3.8). Although "research into the use of mainstream games in education is relatively novel" (Kirriemuir, 2004, p. 3), it is "growing rapidly" *(ibid.)*. Furthermore, a growing number of academic and educational institutions offer gaming-related courses (e.g. game design) and qualifications *(ibid.)* and this development shows that more teaching institutions are looking towards video games to solve the conundrum of students who are disinterested in the curriculum but are highly attracted by new and emerging technologies. Or as

James Paul Gee states, "the theory of learning in good video games fits better with the modern, high-tech, global world today's children and teenagers live in than do the theories (and practices) of learning they see in school" (Gee, 2003, p. 7). Gee further asks, "wouldn't it be great if kids were willing to put in this much time on task on such challenging material in school and enjoy it so much?" *(ibid. p. 5)*.

Just like Gee, Prensky is a strong advocate for learning that is supported by video games. Prensky points out that today's 'tell-test' teaching methods have been introduced after the invention of print made it possible to logically organise (*tell*) information and systematically *test* how much of this information has been ingested (Prensky, 2001a). While he states that this tell-test method has worked "pretty well through the late nineteenth and the early and mid twentieth century" (Prensky, 2001a, p. 75), he argues that this teaching method should be reconsidered in favour of a more learner-centred approach with fun (through games) as the motivator. Prensky claims that fun "create[s] relaxation and motivation" and "relaxation enables a learner to take things in more easily, and motivation enables them to put forth effort without resentment" (Prensky, 2001a, p. 111).

Adding to these positive views of teaching and learning in video games is David Williamson Shaffer who states that video games bring students together rather than separate them like schools do (Shaffer *et al.*, 2005, p. 106). Furthermore, Shaffer explains that games allow situated learning. He gives an example of a game that gives users the opportunity to play and learn about urban planning. Madison 2200[44] teaches players the concepts of urban planning in a scenario that puts the rules into direct context by showing how differing choices and decisions influence the outcomes of a project. Shaffer continues his argument by

[44] http://epistemicgames.org/eg/?cat=19, last accessed: 29.03.2009

stating that corporations, governments, the military and other groups are already using this type of education and that schools need to catch up if they want their students to be engaged and motivated in learning (Shaffer *et al.*, 2005, p. 110).

Schaffer's view is supported by Zyda who states that

> *research in the games arena affects not just the entertainment industry but also the government and corporate organizations that could benefit from the training, simulation, and education opportunities that serious games provide. (Zyda, 2005, p. 25).*

These arguments show that there is an opportunity to use video games for positive character forming and teaching purposes and we can see the vivid interest in educational media. For example, the game *Brain Age* for the Nintendo DS rated rank 4 in the list of top selling games in September 2006[45], following *Pokemon Mystery Dungeon Blue Rescue Team*, *Castlevania Dawn of Sorrow* and *New Super Mario Bros.* The Brain Age add-on game *Big Brain Academy* ranked number ten. A more recent list of the top 5 of bestselling video games of 2008[46] shows three out of the five video games to be non-violent (*Mario Kart Wii, Wii Fit, Guitar Hero III*). It is argued that a possible solution to engagement and learning lies in the domain of video games and it is further argued together with others (Gee, 2003; Foreman *et al.,* 2004; Prensky, 2001a; Randel *et al.,* 1992; Shaffer, 2007) that it is possible to learn from the successes of video games and use their power to attract students to games with an educational background. But not only is it possible to make the subject matter more attractive to students by using video game technology, it may also support them in remembering more

[45] Amazon - List of top selling Nintendo games: http://www.amazon.com/, last accessed: 24.09.2006

[46] Cnet News: http://news.cnet.com/8301-13846_3-10022181-62.html, last accessed: 17.02.2009

of the information that is presented to them. In the next section we will discuss how the use of video games for teaching purposes compares to traditional teaching methods.

2.3.7 Video Games and Teaching

With about 90 percent of U.S. youth between the ages of 8 and 16 playing video games for about 13 hours a week (Harding, 2008), there is a lot of discussion about the dangers of video games as opposed to the educational values. Entertainment is not the primary aim of educationalists or concerned parents who only see that youngsters are spending hour after hour in front of a computer screen playing video games. To them it seems as if their offspring is wasting precious time playing games, which could be better spent studying their math or history books. A number of researchers believe that video games offer a lot of potential for teaching (Aldrich, 2005; Gee, 2003, 2008; Prensky, 2001a, 2001b; Shaffer, 2007; Shaffer *et al.*, 2005; Steinkuehler, 2004) and further evidence for the positive effect of using video games for teaching purposes comes from Randel *et al.* (1992) who conducted a meta-analysis of 68 studies that compares the instructional effectiveness of games to conventional classroom instruction. The studies were separated into seven groups according to the subject matter (social sciences, math, language arts, physics, biology and logic). Within these groups Randel *et al.* reported the influence that games and classroom instruction have on memory retention and motivation of students.

Randel *et al.'s* study is highly complex because they looked at many different factors, related the findings to the respective groups (social sciences, math, language arts, physics, biology and logic) and drew conclusions for each of these groups. The conclusions from these groups are varied, and for those interested in the details the full study is highly recommended. For the present study the relevant parts can be summarised by saying that Randel *et al.* observed a general pattern between video games and memory. They state that "simulations/games show greater retention over time than conventional classroom instruction" (Randel *et al.*, 1992, p. 269). Moreover they state "that games/simulations are more interesting than traditional classroom instruction is both a basis for using them as well as a consistent finding" *(ibid. p. 270)*. However, these statements have to be put in context and when we look at the details of the meta-analysis we see that the majority of studies within the seven groups found no difference in student performance of video games and general classroom instruction (56%). Some found evidence for the positive effects of video games (32%) and only very few studies showed a preference of the classroom instruction over games (5%). The remaining 7% favoured simulations/games, but according to Randel *et al.* "their controls were questionable" (Randel *et al.*, 1992, p. 269). Unfortunately, no further elaboration was provided by the authors as to why the controls were questionable but, they found that in 12 out of 14 studies (only 14 out of the 68 studies investigated motivation), students were more motivated by games than by traditional classroom instruction.

These numbers represent the average across the seven disciplines and Randel *et al.* state that there are wide differences between the usefulness of video games for the respective disciplines and "whether simulations/games should be used for educational purposes depends on subject matter". According to Randel *et al.*, disciplines that benefit most from the use of games include "subject matter areas where very specific content can be targeted and objectives precisely defined" (Randel *et al.*, 1992, p. 269). Such subject matter areas are more likely to show beneficial effects for learning *(ibid.)*.

One of the disciplines where video games proved to be particularly useful is mathematics and Randel *et al.* conclude that

> *computer games are reported to be very effective in improving mathematics achievements scores. Seven out of eight studies on the use of computer math games found the games produced significant gains in math achievements for students in first grade through junior school (ibid. p. 265).*

On the other hand, the social sciences discipline showed the least favourable outcomes for the use of video games. Randel *et al.* report that

> *thirty-three of the 46 studies showed no difference for simulation games over traditional instruction […]. Ten studies favored games […], and three studies favored conventional methods (ibid. p. 264).*

Looking at these wide differences it becomes clear that the overall figures (56% equal, 32% in favour of games and 5% in favour of traditional classroom instruction) have to be distinguished by discipline areas. Randel *et al.* did this to a certain extent but they acknowledge that more studies are needed for a more comprehensive insight *(ibid. p. 270)*.

For now, if even the worst group (social sciences) shows that "72% of games/simulations were at least as good as conventional classroom instruction and 22% of the games were better" *(ibid. p. 270)* it is argued that enough evidence has been presented to justify further investigations, especially into the "subject matter areas where very specific content can be targeted and objectives precisely defined" *(ibid. p. 269)*, like memory for facts.

2.3.8 Criticism

There are, however, critics who look at the video game situation from a different angle and a discussion has evolved about the negative aspects and the possible dangers of video games. The arguments most commonly used against playing video games are that they glorify violence, encourage criminal behaviour and quite often feature sexual themes that are inappropriate for the target audience of teenagers. Video games have been studied in relationship to addiction (Hart *et al.*, 2009; Messerly, 2004) and violent behaviour (Jagodzinski, 2006) and there are activists like Jack Thompson who is vehemently opposed to games like 'Grand Theft Auto' (Linn, 2005) in which players drive a car through a city and have to "succeed" in criminal activities to "master" the game. Furthermore, players can use their cars to run over and kill harmless pedestrians without much risk of getting caught by the in-game police force. There has been uproar in the media about the 'Hot Coffee' mod (to mod means to modify the original game), which granted access to a mini-game within Grand Theft Auto that allowed the player to control the actions of the character during intercourse with one of his in-game girlfriends. The basis of the controversy was not so much the sexually explicit content itself but the fact that the game was rated as being suitable for teenagers 14 years and over (Lohr, 2005).

Another example of such inappropriate content includes the level of violence of the 'first-person shooter' game 'Doom'[47] in which the player fights against alien monsters with an expanded weapons arsenal. The imagery of the killing sequences in 'Doom' is highly detailed and it has been suggested (Carnagey *et al.*, 2007) that continued exposure to such scenarios in an environment without any

[47] http://www.idsoftware.com/games/doom/doom3, last accessed, 30.07.2009

consequences can lead to a desensitisation to real-world violence of the mostly adolescent players. Often a connection is made between the computer game 'Doom' and the 1999 Columbine high-school massacre in which two teenagers killed twelve students and one teacher before shooting themselves. The two boys are reported to have played 'Doom' frequently (Johnson *et al.*, 1999).

While agreeably '3d shooters' like *Doom, Counterstrike*[48] and *Unreal Tournament*[49] are violent at first glance and do not seem to have much educational value, it could, however, be argued that they improve the hand-eye coordination of players which may later help them in real-life situations. Rosser (2007), for example found that surgeons who played video games for more than 3 hours per week made 32% fewer errors and completed a surgical training task 24% faster than their non-playing colleagues. Furthermore, it could be said that the players work out hierarchies of who is best in communication, who is good in strategic planning, who is a leader and who is not. However, these training aspects are not seen as such by everyone and the negative views towards modern technology mainly focus on the detrimental effect of video games on society values (Seel, 1997; Linn, 2005).

John Seel, seems particularly sceptical of the developments of technology and the "potential impact upon character development" (Seel, 1997, p. 17) that video games, MTV and the Internet can have on the teenager generation. Although he claims that generally he is not opposed to new technology he states that technology is "a Faustian bargain which reaps great benefits often at a great price" (Seel, 1997, p. 21). Seel is concerned about the potentially negative influence of video games which in his opinion increase the proliferation of selfishness in the younger generation. He argues that "we are fast becoming a

[48] http://store.steampowered.com/app/240/, last accessed: 18.12.2008

[49] http://www.unrealtournament3.com/, last accessed: 18.12.2008

brave new world of infantile personalities whose ethic is instant self-gratification" (Seel, 1997, p. 28). This instant self-gratification can be seen in the rapid character or career development in computer games. For example, the career mode in the racing game *Gran Turismo*[50] offers quick rewards and easy access to prize money for winning races. One can progress quickly through the ranks and with the prize money one can buy new and better cars. In this context it means that - compared to real life - the players get a faster reward for the work they put in. Seel expresses concern that human values are at stake and that in order to save these values "a disciplined use" (Seel, 1997, p. 21) of technology is necessary. He states that "this is especially true of younger children who are unable to make the associative distinctions between fantasy and reality" (Seel, 1997, p. 22). The game becomes the child's reality and Seel argues that this is the reason why computer games hold such a dangerous potential. Another concern of Seel is that electronic entertainment fosters the "spoiled only child syndrome" (Seel, 1997, p. 28) where the single personality is never put in question. Thus, the spoiled child develops an "inability to be serious about anything" and "all of life is supposed to be fun or amusing" (Seel, 1997, p. 28). His view is backed by others (Chamberlin, 2000) who state that there is "consensus within the public health community on the negative effect violent entertainment has on children" and that "this generation of children is schooled in the art of violence by a private tutor, while parents remain unaware of the problem" *(ibid. p. 49)*.

To a certain extent the author of this thesis agrees with the above concerns and the negative effects that *overexposure* to video games, television and other forms of technological entertainment can have on the development of the younger generation. These reports and viewpoints are however only one side of the coin and this negative attitude towards video games may need revision because, as

[50] http://www.gran-turismo.com/, last accessed: 18.12.2008

we have seen, there is also a meaningful use of video games, which brings education and playing games together. Over the centuries there has been criticism of technology, industrialisation, progress, globalisation and so on. However, as we have seen with, for example, industrialisation there have been major improvements to quality of life and the average standard of living and yet there are many negatives society has yet to deal with. This thesis acknowledges that as with any form of play, video games can have a dark side, but they also offer a lot of promise particularly for education and learning. Video games and other media can be educating and if used correctly they can form the character of players in a positive way. Seel himself gives a lead in this direction when he states that "character is the embodiment of virtue through the training of repeated choices of good behaviour" (Seel, 1997, p. 26) and "character formation [...] is the process whereby right choices are learned and become a pattern of behavior" *(ibid.)*.

Thus, it seems that even the critics agree that video games influence character formation of video game players. It is, however, a matter of which content is provided. Therefore, it was decided to create a video game-like virtual environment (see chapter 3) that teaches history. With this virtual teaching environment we sought to investigate how much information players in fact remember from the information that is conveyed in such an environment. Furthermore, it was investigated if the remembrance rate for facts that were learned from this virtual history lesson could be improved by playing a certain style of music in the background. One might ask what music has to do with memory and the answer is that we have indicated in the various sections of this chapter, that engagement and fun are important for learning, however, these things are often missing in educational virtual environments. Music, however, holds the potential to engage players and in the next section we will discuss the different effects that music can have and how it influences us in different situations, including learning and video gaming.

2.4 Music

Play, we said, lies outside the reasonableness of practical life; has nothing to do with necessity or utility, duty or truth. All this is equally true for music. (Huizinga, 1949, p. 158).

Music is often referred to as the 'Universal Language' (Davies, 2000; Herbert, 1990; Vos, 2006) and for every person it has a different meaning and importance. For some people music is a way to relax, get inspired or excited, for others it is "the art of expressing or causing an emotion by melodious and harmonious combination of notes" (Discoveries, 2006). As we will see, in the present context music bears the potential to help people concentrate on one task by blocking out distractions and thus facilitating the human memory process.

Music has been an integral part of our cultures long before humans began living in organised societies, around 8000 BC (Unstead, 1984, p. 5). There is no written record about the time when singing became part of human tradition but with modern technology it is possible to estimate the age of musical instruments. The earliest evidence for such musical instruments could be validated from bird-bone pipes from Geissenkloesterle, Germany, which date back to about 36.000 years BC (d'Errico *et al.*, 2003, p. 39). Ever since then music was part of our lives and as d'Errico expresses it, "there can be few documented societies, indeed few individuals, for whom musical expression of one kind or another does not play, consciously or unwittingly, a significant role" (d'Errico *et al.*, 2003, p. 33). Many different musical styles and genres evolved throughout the centuries and in some instances music is not only used for entertainment but also for healing purposes. Music is used to treat alcohol addiction (Gallant *et al.*, 1997) or to soothe the symptoms of the burn-out syndrome of elementary school teachers (Cheek *et al.*, 2003). Other therapies use music to treat children with autism (Bracefield *et al.*,

2000) and Attention Deficit Hyperactivity Disorder (ADHD) (Chambers, 2008; (Samuels *et al.*, 2005; Tomatis, 2006). In the following section we will see how music is actually able to support single-tasking by occupying one brain half and thus freeing processing power of the other brain half to focus on one task.

2.4.1 Effects of Music on Brain Processes

> *Music gives a soul to the universe,*
> *Wings to the mind,*
> *Flight to the imagination ...*
> *And life to everything.*
> *Plato*

The research into the effects of music on brain processes and learning is controversially discussed. Critics like Koenen (2005) claim that music nowadays is sometimes used to manipulate the masses. Koenen states that music is used to stop people from thinking by constantly making them feel good with the right kind of music. In his own words he claims that "[music] is [..] being played - not just in your local Starbucks, but in malls, dentist offices, and while you're on hold for the next available representative - to prevent thought" (Koenen, 2005, p. 139). There is a whole industry that lives from creating 'soundscapes' for customers. Muzak is one such example and they "create experiences that link customers with companies" (Muzak, 2006). On their Internet website they state that

> *[Music's] power lies in its subtlety. It bypasses the resistance of the mind and targets the receptiveness of the heart. When people are made to feel good in, say, a store, they feel good about that store. They like it. Remember it. Go back to it. (Muzak, 2006)*

Some companies (e.g. the Deutsche Telekom) even put a patent on a certain melody line (DPMA, 2006) to ensure that their company jingle is unique and reminds the customers of their services wherever they hear the melody. As Davies says, "Advertisers count on the public remembering their products because of an advertising jingle or song" (Davies, 2000, p. 151). Koenen states that this pervasiveness of music prevents him from thinking deeply about something and "the innocuous show tunes and worn-out oldies lap over my thoughts like a warm bath. Don't think, don't think, relax, relax, don't think" (Koenen, 2005, p. 140).

Despite these concerns, Koenen actually offers an argument *for* the use of music by stating that music prevents thought (Koenen, 2005, p. 139). This argument is also used by Restak (2004), however in a positive context, when reporting about surgeons who are listening to classical music while operating. Restak states that in this example the music is not interfering with the operation process but instead helps the surgeons to concentrate on their current task. Restak argues that "the music isn’t a distraction but a way of blocking out all of the other distractions" (Restak, 2004, p. 70) and that "music and skilled manual activities activate different parts of the brain, so interference and competition [of different brain areas] are avoided" (Restak, 2004, p. 71). Restak refers to a general behaviour amongst surgeons but does not offer more details or hard data, thus the validity of his claims cannot be verified directly.

One study, however, that is in line with the comments made by Restak, offers the details of a rigid experimental method. Allen *et al.* (1994) investigated how music affects surgeons' task performance in a backward counting task if they listened to music while performing the task. The investigators gave some participants pre-selected music while others were allowed to bring their own favourite music. A control group received a music-free condition. Those participants who listened to the investigator-selected music performed significantly better than participants who did not listen to music at all. Notably, the participants who were allowed to bring their own music performed significantly better in the backward counting task than those participants who listened to the investigator-selected music. While Allen and Blascovich indicate that the surgeons' emotional state might have been influenced by the fact that they were listening to their own favourite music (which in turn improved their speed and accuracy), it is striking that even those participants who listened to the investigator-selected music performed significantly better than participants in the music-free condition.

Of course, there are some restrictions in regards to these findings, like for example, that the results cannot be generalised because inferences on real-world tasks cannot be drawn from improved performance in a backward counting task. Moreover, the investigators report that all participants were self declared music enthusiasts interested to participate in the study, thus it cannot be speculated if similar results would have been discovered with non-music enthusiast surgeons. Furthermore, the sample of this experiment was restricted to surgeons, therefore the results of this study cannot be generalised to the general population. However, for this particular task music was of benefit and further compelling evidence for the usefulness of music for educational purposes comes from McFarland and Kennison (1988).

In their study McFarland and Kennison (1988) found that participants who had to solve a tactual maze task with either their right or left hand performed badly when listening to music on the ear that was on the same side of the body as the hand they were performing the maze task with. McFarland and Kennison explain that this reduced performance is due to the fact that two tasks were performed by the same brain half at the same time, causing 'intrahemispheric competition' in that brain half. The most interesting part of this study is, that it did not only show that our brain is able to perform the maze task better if the hand is used that is contralateral (on the other side of the body) to the ear that is listening to the music, but it also showed that when participants listened to music in both ears (binaural listening condition) the number of trials needed to figure out the maze dropped dramatically when the right hand was used for this task.

As can be seen in Figure 5 under the 'No Music' condition the mean number of trials that participants needed to complete the maze task was 20.42 if they used their right hand. If they used their left hand, participants needed 19.00 trials on average. The results from the 'Play music to the left ear' and 'Play music to the right ear' condition (see 'Left Ear', 'Right Ear' in Figure 5) clearly support the initial hypothesis of McFarland and Kennison, that if music is played to the ear opposite to the hand performing the maze task, the mean number of trials needed to solve the task is lower (i.e. better) than if music is played to the ear on the same side of the body of the hand used to solve the maze.

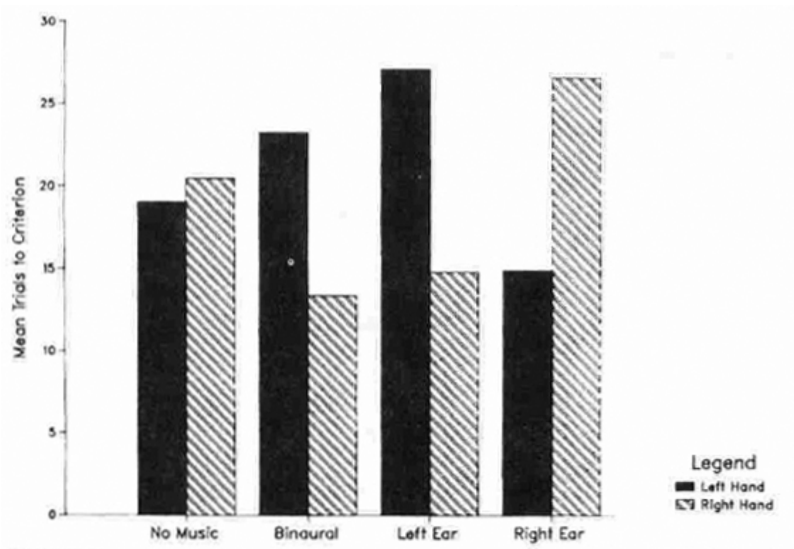


Figure 5: Listening to instrumental music frees processing performance of the left brain half - Source: (McFarland *et al.*, 1988)

However, if we look at the 'Binaural' condition we find the surprising result that participants performed a lot better when they were using their right hand in order to solve the task (Binaural Listening, Left Hand used: 23.17 mean trials vs.

Binaural Listening, Right Hand used: 13.13 mean trials). What makes this result even more surprising is that performance is better than the 'Left Ear - Right Hand' condition (14.75 mean trials) and shows the effect of what McFarland and Kennison call 'Intrahemispheric and Interhemispheric Competition'. Intrahemispheric competition occurs when two tasks compete with each other in the same brain half (hemisphere). Interhemispheric competition occurs when the two brain halves communicate with each other and processing power of both brain halves is wasted when the frequency of communication is too high. Their claim is supported by Hass and Whipple's earlier experiments (Hass *et al.*, 1985) about concurrent tasks in the two cerebral hemispheres. They say that

> *the effects reported here [in their experiments] demonstrated the interfering effect of a concurrent memory task on performance on a high-level laterality task. The verbal memory task removed a LH [Left Hemisphere] advantage on word categorization, and a pictorial memory task interfered with picture categorization in the RH [Right Hemisphere] (Hass et al., 1985, p. 21).*

At this point it should be emphasized that the music used in McFarland & Kennison's and Allen and Blascovich's experiments was in both cases classical and/or instrumental music. In fact, the type of music could be the reason why task performance improved, as we will discuss below. Notably, all participants in the Allen & Blascovich study who were allowed to bring their own music chose to bring instrumental music (46 Classical, 2 Jazz, 2 Irish folk). This choice is highly interesting and the reason why the surgeons freely chose instrumental music could be that music with lyrics interferes with other brain processes as Pring and Walker (1994) report. Their study investigated the connection between instrumental and vocalised music and task performance. They found that 'devocalised' background music interfered with Short-Term Memory compared to music that is mostly instrumental, like classical music. Devocalised in this context means that Pring and Walker removed the sung lyrics from popular nursery rhymes and presented participants with the remaining instrumental music. They found that the performance of participants in a number-recall task was significantly lower if they listened to the version of the nursery rhyme with removed lyrics as compared to instrumental classical music. Pring and Walker argue that the reason for this reduced performance is that the brain attempts to supplement the removed lyrics and this supplementary process requires a certain amount of the processing power of our brain (Pring *et al.*, 1994, p. 165). Furthermore, they state that the same brain regions were activated as if participants were listening to the nursery rhyme with the lyrics. Restak also investigated this point. He reports that

> *imagining or visualizing a complex or skilled movement can help improve performance […]. PET scans show that the brain areas involved in such motor imagery surround the areas that are activated when the movement is actually made. (Restak, 2004, p. 189)*

Another factor that influences learning is the frequency of our brain waves and according to Dryden & Vos in order "to learn faster you slow down the brain" (Dryden *et al.*, 2001, p. 309). They argue that a state of 'relaxed alertness' is most advantageous for learning. This 'relaxed alertness' state of mind is called the alpha state and the brain works at a frequency between 8 - 12 Hertz. Dryden and Vos state that this is "the brainwave activity that links best with the subconscious mind" (Dryden *et al.*, 2001, p. 169). Figure 6 shows the alpha state in comparison with the other frequencies of our brainwaves as recorded by an EEG machine. The other brainwave frequencies include the beta state, which is present when we are wide awake and highly concentrated on what we are doing (e.g. arduous work, stress). Our brain works at 13 - 25 cycles per second (Hertz) in this state. However, this frequency is "not the best state for stimulating your long-term memory" (Dryden *et al.*, 2001, p. 169) and the alpha state is to be preferred.

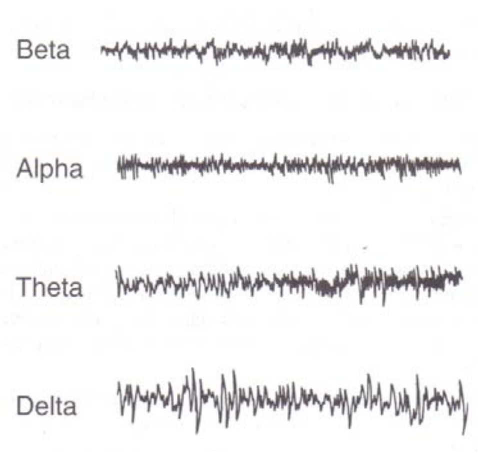


Figure 6: The different brainwave frequencies - Source: Dryden & Vos (2001)

The two remaining brainwave frequencies displayed in Figure 6 are the theta and delta state, which equal to 4 - 7 Hertz for the theta state and 0.5 - 3 Hertz for the delta state. While the theta state can be best described as being the "twilight zone between being fully awake and fully asleep" (Dryden *et al.*, 2001, p. 169), the delta state is reached when we are in deep sleep. Decker says about this delta state that it is the state that we know least about but that this is the state where our body grows and our organs are activated (Decker, 1999). From these explanations it becomes clear that the alpha frequency (8-12 Hz) is the optimal state for learning new information.

One teacher who actively integrates music into language teaching practice is Lozanov (1992), a Bulgarian psychologist who developed the concept of 'Suggestopedia' also known as Suggestology. Before each language lesson students listen to relaxing music and the aim of this exercise is "to tune out other distracting thoughts, and to place the brain in a state of 'relaxed alertness'" (Dryden *et al.*, 2001, p. 179). In the following language lessons music is used alongside dialogs spoken in the foreign language. The whole concept uses music as a vehicle to immerse students in the learning situation and keep their minds away from other distractions.

Throat singing used by the Siberian Chukchi (Nattiez, 1999) in hunting rituals and the ceremonies by the Australian Aborigines which are accompanied by the trance-like sound of the didgeridoo suggest a similar reason. Music and songs might be used in order to block out other worries (like problems in the family or with other members of the clan), which are less important for survival. The preparations for the ceremonies occupy a lot of time and every member of the group is involved. In the ceremony itself all senses are flooded with stimuli, thus the participants fall into a state of trance - they "zone out" and through the ceremony they concentrate on just one task – the preparation for hunting.

All of the above studies are scientific publications that are accessible through public and University libraries but probably not very well known to the general public. However, a study conducted by Frances Rauscher, Gordon Shaw and Catherine Ky (Rauscher *et al.*, 1993) brought the effect of music on learning to public attention. Their study, involving 36 college students, is mostly known for the so-called 'Mozart Effect' due to the fact that Rauscher *et al.* used a Mozart sonata for their experiments. Specifically, Rauscher *et al.* investigated the effect of listening to classical music before taking a spatial reasoning test. They found that those students who listened to 10 minutes of Mozart's Sonata for two pianos in D major, K448, scored 8 - 9 points higher in a subsequent spatial ability IQ test, compared to those who listened to a relaxation tape or to no audio stimulus at all. The results are heavily discussed and other researchers have tried to replicate the results, some were successful (Rideout *et al.*, 1998), others were not (McKelvie *et al.*, 2000; Steele, 2003).

In a follow-up study, conducted with young children aged 3-4.9 years old, Rauscher and Shaw, together with colleagues (Rauscher *et al.*, 1997), investigated the effect of musical training on spatial-temporal reasoning. Note that the emphasis in this study was on musical training unlike listening to Mozart as investigated before. 78 children from both genders were included in the tests and 34 of those children were given piano lessons while the other children were given singing lessons, computer lessons or no lessons at all. Rauscher *et al.* found that the group that was given the piano lessons "scored 34% higher on tests designed to measure spatial-temporal reasoning skills" (Burack, 2005). Rauscher's and Shaw's findings from this later study (the effect of musical training on learning) are strengthened by the results of Gardiner *et al.* (1996) who found that musical training of pupils (5 - 7 years of age) increased their learning outcomes, especially in mathematics (Gardiner *et al.*, 1996). Gardiner *et al.* observed 96 pupils in eight first-grade public-school classrooms where the test groups took part in a curriculum that included music and visual-arts. In their study they found that

> *those in the test arts classes started behind the control children […] but after seven months, they had caught up to statistical equality on reading and were now ahead on learning mathematics. (Gardiner et al., 1996, p. 284)*

Returning to the original experiments by Rauscher *et al.* (1993) it should be mentioned that there is not only controversy about the replication of the effect but also experiments have been conducted that indicate that the Mozart effect might have nothing to do with Mozart in particular. Instead the reason for the improved performance in the spatial reasoning test might be arousal and mood that were positively influenced by the Mozart piece. Thompson, Schellenberg and Husain (2001) conducted a study that investigated how these two attributes were affected by a pleasant and energetic Mozart piece in major mode and a slow, sad Albioni piece in minor mode. Two groups were assigned to each of the conditions and within each group participants listened to the "music condition [and] were retested 7 days later in the silent condition, and vice versa" (Thompson *et al.*, 2001, p. 249). Figure 7 shows that participants from both groups (Mozart, Albioni) performed equally well if they were assigned to the 'Silent' condition. However, those participants who listened to the pleasant Mozart piece in major mode performed significantly better in the associated paper-folding-and-cutting task as opposed to the second group who listened to the slow and sad Albioni piece in minor mode.

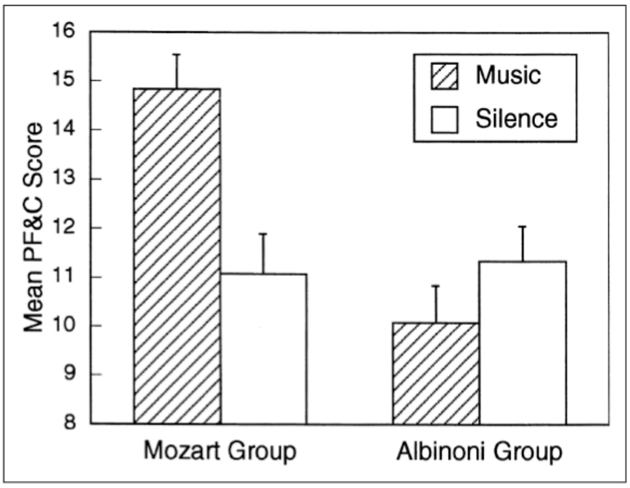


Figure 7: Participants' mean scores on the paper-folding-and-cutting task after sitting in silence or listening to music. Source: (Thompson *et al.*, 2001)

In contrast to Rauscher's earlier experiments, Thompson *et al.* thus conclude

> *it is possible, then, that the Mozart effect has little to do with Mozart in particular or with music in general. Rather, it may represent an example of enhanced performance caused by manipulation of arousal or mood. (ibid. p. 248)*

Ilie and Thompson (2006) further investigated how changes in pitch and tempo affect valence ratings and whether the musical stimuli were perceived as positive or negative. They found that low-pitched music and fast tempo music increased energetic arousal *(ibid.)*.

The experiments and studies discussed above are without exception relatively recent but it is not that the usefulness of music and its effects on humans has only been investigated in the last 60 years. As Barber and Barber say "The effects of music and musical interventions on the mind, body, and spirit are evident throughout history and across culture" (Barber *et al.*, 2005, p. 8).

Aristotle, for example, divides education into three plus one basic sections – reading, writing, gymnastic exercises and music (and sometimes drawing is added to this curriculum). Aristotle was a scholar of Plato, who himself was a disciple of Socrates the forefather of Greek philosophy. While Socrates did not write down any of his thoughts, Plato conserved many of Socrates' ideas and expressed them in e.g. the *Dialogs of Plato.* In these dialogs Plato lets Socrates say to Glaucon:

> *Musical training is a more potent instrument than any other, because rhythm and harmony find their way into the inward places of the soul, on which they mightily fasten, imparting grace, and making the soul of him who is rightly educated graceful, or of him who is ill-educated ungraceful. (Plato, 1892)*

As noted, these findings were stated more than two millennia ago in ancient Greece and more contemporary evidence for the motivational effect of music comes from Eady and Wilson (2004) who cite an unpublished doctoral thesis by Weisskoff (1981) in which 201 fourth and sixth grade children received language lessons – with or without background music. They report that "students who received the music condition scored significantly higher with regard to continuing motivation" (Eady *et al.*, 2004, p. 243). Looking at the thesis itself (Weisskoff, 1981) we find that there were two aspects to the study – achievement (i.e. task performance in language games associated with the presented stimuli) and continuing motivation (CM). Where task performance was not influenced by music, CM was positively influenced and "there was a significant […] relationship between the music and the participants' desire to do more word games on their own time" (Weisskoff, 1981, p. 77).

We too argue that music has a motivational character and that music is one of the major reasons for the attraction of teenagers to video games. We think that the state of total immersion that can often be observed with the above-mentioned fantasy-game-worlds is partly due to the music that is played throughout the course of the games. Contrary to Weisskoff however, we argue that music can have a beneficial effect on memory for facts. It is acknowledged that Weisskoffs' experiments were conducted in the language arts domain and not in the area of memory as in the present study. Furthermore, the present study makes use of virtual environments for the investigations and might thus produce different results. However, there seem to be very few studies (e.g. Moreno (2000), discussed in section 2.4.3) that investigate the effect of music on memory in virtual environments. For this reason, the best possibility to find other relevant work was to look for such evidence in related areas where more research has been conducted and results reported. Zehnder and Lipscomb have come to the same conclusion for their study of the role of music on immersion in video games stating that because "there have been very few experimental or theoretical studies of the role of music in the perception of video game stimuli [...] we begin our reviewing literature on the role of music in the perception of film" (Zehnder *et al.*, 2006, p. 241). Thus, let us explore the findings of the effect of music in movies.

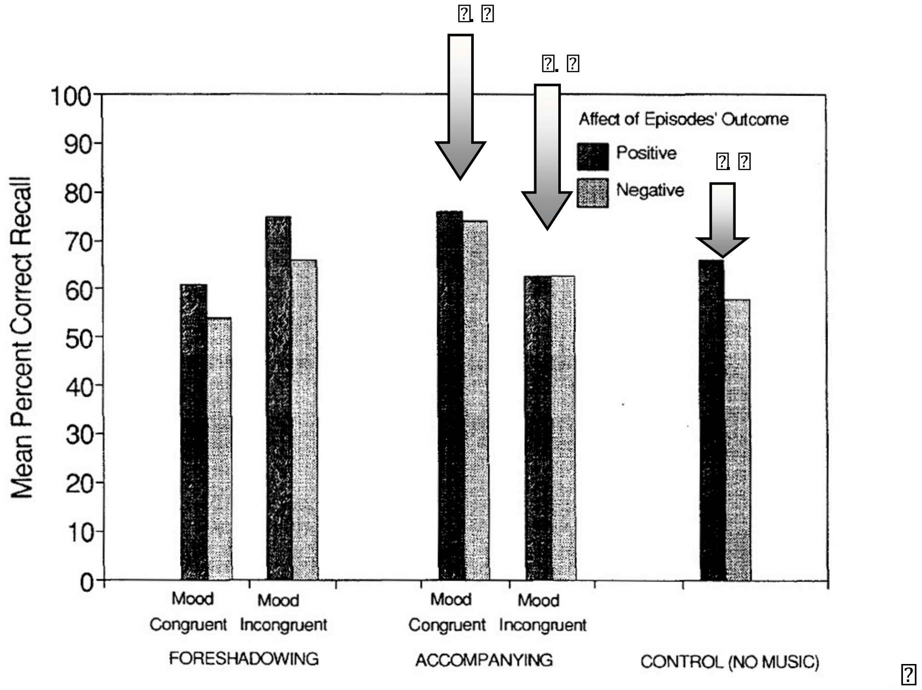
2.4.2 Soundtracks in Movies

Zehnder and Lipscomb state that "it is an undeniable fact that music plays a significant role in the motion picture experience" and they continue by saying that "it is the belief of the present authors [of their book chapter] that the musical soundtrack plays a similarly important role in the context of video games" (Zehnder *et al.*, 2006, p. 243). Don Veca, the audio director for the Lord of the Rings game *The Return of the King*[51], says that "we're getting to the point where we're expected to sound like a movie" (quoted in Jackson, 2004) and

[51] http://www.ea.com/official/lordoftherings/returnoftheking/us/home.jsp, last accessed: 17.02.2009

Marilyn Boltz states that "Filmmakers have long acknowledged this function [the expression and conveying of feelings] of music and have developed various techniques in which music is used to exert certain effects upon a viewing audience" (Boltz *et al.*, 1991, p. 593). Consequently, in this chapter, we will present research that has been conducted in this area.

Boltz, Schulkind and Kantra, for example, investigated the effects of background music on the remembering of filmed events (Boltz *et al.*, 1991) and found that participants remembered visual information (i.e. movie scenes) better if such information was accompanied by mood-congruent music. In their experiment, Boltz *et al.* presented 60 psychology students with 16 different videoclips. Each videoclip was between 3-4 minutes in duration and had a distinct beginning and end so that it could be considered an 'episode'. Half of the 16 episodes resulted in a happy/positive ending and the other half in a sad/negative ending. Along with these episodes, participants were presented background music taken from the original films. The affect of each musical tune was rated in preceding tests as being positive or negative and the musical tunes were then assigned to the episodes (no episode was presented along with its original background music). Each episode was combined with two musical tunes (positive and negative), creating 8 mood congruent video/music pairs (4 positive video/positive music and 4 negative video/negative music) and 8 mood-incongruent video/music pairs (4 positive video/negative music and 4 negative video/positive music), resulting in 16 pairs of video episodes crossed with musical tunes. The combination of videoclips and background music was then presented to participants. A control group watched the videoclips without a musical condition (see Figure 8). (Note: There was also a third group that watched a 'foreshadowing' condition. The results are not directly related to our present study, hence, this group is omitted from the current discussion)


Affect of Episodes' Outcome
Positive
Negative
Mean Percent Correct Recall
100
90
80
70
60
50
40
30
20
10
0
Mood Congruent
Mood Incongruent
FORESHADOWING
Mood Congruent
Mood Incongruent
ACCOMPANYING
CONTROL (NO MUSIC)

alone. Finally, the third subgroup was told to direct their attention to both stimuli, video *and* music. There was no control group in this experiment. The analysis of the experiment data revealed several interesting results, of which we will look at the group with the mood-congruent condition only, because it is most relevant to our study. In this group Boltz found that those participants who concentrated on the *music alone,* remembered exactly the same amount of film-scenes than did those participants who were asked to concentrate on the *film alone*. The recall performance for both conditions was 83%. This means that those participants who focused on the music alone, incidentally learned the visual information without making the original effort of attending to the visual stimulus. Furthermore, Boltz found that participants from the third sub-group (attending to video *and* music) remembered 92% of the visual information! Boltz states that "the divided-attending group even remembered film clips *better* than did those who focused on the film alone" (Boltz, 2004, p. 1199). This seems to indicate that "the two dimensions became integrated into memory as a unified whole" (Boltz, 2004, p. 1199).

It should be said that the author of this thesis also argues that music takes an important role in memory processes and that just like for movie experiences (Boltz, 2001, 2004; Boltz *et al.*, 1991) there is a potential relationship between music and memory in virtual environments. The experiments reported in Chapter 4 test these claims in a situation of role-playing games and immersive virtual environments. However, before looking at these results we will describe research that has been conducted in the area of video games, music and cognitive processes.

2.4.3 Music in Video Games and Effect on Cognitive Processes

A growing number of articles investigates the use of virtual environments and video games for teaching purposes (Barab *et al.*, 2005, Gee, 2008, Ritterfeld *et al.*, 2006, Shaffer *et al.*, 2005, Steinkuehler, 2004) but despite an extensive literature search on research related to the effect that music in video games has on memory and/or learning, only one study was found which directly investigates the effect of music in multimedia learning environments on retention (Moreno *et al.*, 2000). In these experiments environmental sounds and background music were added to animated explanations of the formation of lightning and the operation of braking systems. Moreno & Mayer found that the background music had a detrimental effect on memory for the details of the two animated explanations and the addition of environmental sounds showed no improvement on memory in the first explanation (lightning) and a detrimental effect in the second explanation (braking systems). Moreno & Mayer state that "the different results for sound effects between experiments may be related to differences in the coordination of the sounds and their duration" (Moreno *et al.*, 2000, p. 124). The experiments by Moreno & Mayer went for 3 minutes and had another 3 minute cued recall period afterwards in which either music, sounds or both (depending on condition) were played again to participants. However, particularly for the background music condition a questionable choice exists as they reportedly used a 20 second loop of "synthesized" and "bland" (Moreno *et al.*, 2000, p. 119) music to play as background music. This bland character of the loop could be the reason why participants in their experiments performed worse under this condition. Moreno & Mayer's conclusion is that if auditory elements are added to multimedia learning lessons, these auditory elements have to be coherent with the material and should be used in moderation; otherwise a cognitive overload is the result. Apart from this study, three studies were found that deal with the influence of music on cognitive processes in video games, however, either these studies did not present music and the experiment stimulus at the same time or they did not investigate memory as such.

The first study investigated the effect of playing a computer game or listening to music on recall of words and was conducted by Alin and Nolin (1987) who found that participants who were playing a computer game for 15 minutes *after* listening to a sequence of 20 spoken words - which were played to participants from a cassette tape - remembered less than did the control group which listened to music instead of playing the game. The experiment consisted of two age groups (children 10-11, adults 35-45) and used two sets of words, high-frequency words and low-frequency words. After presentation of the words one group of participants played 15 minutes of a fire-rescue game displayed on a small, handheld electronic gaming device called 'Nintendo Game & Watch'. The task of the game was to save people who were jumping from a burning building by catching them in a canvas and manoeuvring them to a nearby ambulance car. With increased playing time the frequency of falling men increased and it became harder to catch people jumping down from the building. Alin and Norlin say that this game "requires total concentration" and the results of the testgroup compared to the group which listened to music instead of playing the game show "an interference effect which influenced the storing process or the retrieval or both" (Alin *et al.*, 1987, p. 7). The consequences of this interference effect are that the adult participant group that played the game recalled a mean of 3.53 of high-frequency words compared to 3.93 of the adult participant group listening to music after the exposure to the wordlist. The results for the children participant group were 3.27 and 3.87 respectively. Consequently, Alin and Norlin concluded that "listening to music did not have such an [interfering] influence" (Alin *et al.*, 1987, p. 7).

Another related study by North and Hargreaves (1999) investigated how competing tasks affected performance of other tasks. To be more precise, North and Hargreaves evaluated the effect of low arousal (LA) and high arousal (HA) music on the performance of contestants who were participating in a driving game while at the same time conducting a backward counting task. The LA music condition played at a tempo of 80 bpm (beats per minute) and at a volume level of 60 dB (decibel). The HA version was played at a tempo of 140 bpm and had a volume level of 80 dB. The experiment sought to investigate which of these two musical conditions (LA or HA) would compete more with a backward-counting task and participants' driving performance in the racing game simulation. North and Hargreaves investigated the effect of this cognitive competition by observing lap times of participants under the LA and HA version and by letting participants do a backward counting task or not. Numerical data is not available but when looking at Figure 9 it becomes obvious that lap times are not significantly different between the LA and HA condition if participants were performing the backward counting task (upper solid line). According to the figure participants needed approximately 115 seconds for one lap if they were listening to the LA music condition and approximately 120 seconds if they were listening to the HA music condition. However, if participants were void of the backward counting task (dashed line), they not only performed better in general, but lap times under the LA music condition were significantly lower than under the HA condition. If participants were listening to the HA version (right side of the graph), they needed approximately 100 seconds on average per lap. Comparatively, participants only took 65 seconds for each lap if they were listening to the LA music condition. This means an increase of mean lap time of 35 seconds which shows that the faster and louder HA version of the musical piece required more cognitive processing space and left less processing power for the original racing task.

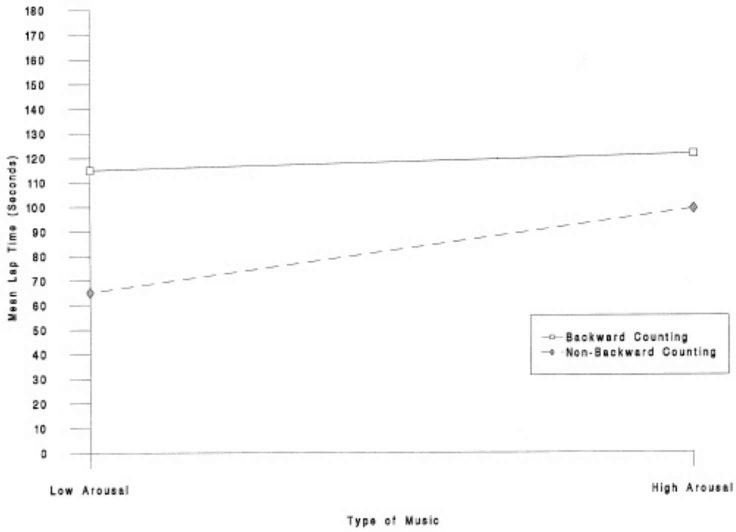


Figure 9: The effect of two types of music and backward-counting on mean lap time - Source: (North *et al.*, 1999)

A similar study conducted by Yamada (2002) used a control group without music to test lap performance of participants in a racing game under different musical conditions. While the overall claim is that music negatively affects lap performance (contrary to North & Hargreaves findings), this might be due to the tempo of the musical pieces used in the experiments. Unfortunately, the paper does not offer information about the bpm count of the various musical pieces. However, looking at the titles and genres of the pieces, it appears that most pieces were rather fast paced which would be consistent to North & Hargreaves' findings. Interestingly, one piece that can be clearly identified as slow tempo (the title 'Energy Flow' by Ryuichi Sakamoto) by its genre of 'New-Age' music (which by definition[52] is composed at a slow tempo) shows a beneficial effect against most other musical stimuli (Yamada, 2002). Lap performance under this musical stimulus is even slightly (but not significantly) better than the 'No-Music' condition.

[52] http://en.wikipedia.org/wiki/New_Age_music, last accessed: 17.02.2009

2.5 Hypothesis

The findings of the existing literature suggest that listening to music can improve spatial temporal abilities (Rauscher *et al.*, 1993), positively affect performance in a paper-folding-and-cutting task (Thompson *et al.*, 2001) and improve participants' performance in a maze finding task (McFarland *et al.*, 1988). Furthermore, it has been shown that surgeons perform better in a backward counting task when listening to music (Allen *et al.*, 1994) and that language is learned more effectively if accompanied by music (Lozanov, 1988). Moreover, positive effects of musical training have been identified (Aristotle, 1885; Rauscher *et al.*, 1997) and memory for movie scenes improved when accompanied by mood-congruent music (Boltz *et al.*, 1991). One study showed that background music and environmental sounds in multimedia learning had a detrimental effect on memory (Moreno *et al.*, 2000). Three studies were found that investigated the effect of music on cognitive processes in video games (Alin *et al.*, 1987; North *et al.*, 1999; Yamada, 2002). Unfortunately, the findings from these studies showed some contradictory results, which is possibly due to different experimental designs, different sample sizes and different participant cohorts.

Therefore, the results from these studies were not directly applicable to the present study as was desired and open questions from the investigated research areas prevail. Boltz, Schulkind and Kantra, for example, state that "although some investigators have examined effects of background music on emotional reactions, the impact of such music on cognitive processing activities remains an unexplored area" (Boltz *et al.*, 1991, p. 593). Zehnder and Lipscomb have come to the same conclusion with specific regard to video games and acknowledge that "there are very few studies of music in video games available" (Zehnder *et al.*, 2006, p. 241). Furthermore, Moreno & Mayer (2000) used a multimedia learning environment and not an immersive virtual environment for their study. Moreover, Thompson *et al.* (2001) suggest that the Mozart effect has nothing to do with Mozart in particular but is due to increased arousal and lifted mood that are influenced by tempo and mood (major, minor) of the music that is being played.

Thus, it was imperative to further investigate the effect of at least one of these attributes and because differing results (Lozanov (1988, 1992); North & Hargreaves (1999); Thompson *et al.* (2001); Yamada (2002) have been revealed for tempo of musical stimuli, it was decided to investigate the effect of this musical attribute further. Additionally, Randel *et al.* (1992) found evidence that educational video games and simulations lead to a higher retention rate. Furthermore, they found that video games have a higher likelihood to motivate students to learn than traditional classroom instruction. However, the studies that Randel *et al.* reviewed in their meta-analysis reach back to the 1960's and it is likely that the computer games used for those studies were rather rudimentary if one was to compare them with the capabilities of contemporary video games. Thus it is likely that contemporary video games could be even more powerful as an educational tool especially since Randel *et al.* state that "given the interest that games invoke and allowing for different learning styles or preferences, using simulations/games should be considered [for education]" (Randel *et al.*, 1992, p. 270).

As was said before, none of the evaluated studies investigates the effects of music on memory of users in video games/virtual environments. Therefore, the research question

> *How does background music in virtual environments affect human memory of facts that are conveyed in such virtual environments?*

remains.

The lack of knowledge in this area revealed a need for new data to be collected, analysed, interpreted and added to the existing body of knowledge. Thus, it was decided to create a virtual environment that would allow testing the effect of different musical pieces on memory of users. Furthermore, it was decided to investigate whether ambient background music helps students to concentrate on one task - learning - just like it helps surgeons to cut out distractions and concentrate on the operations they are performing. The combination of the results from related research areas suggests the following hypothesis for the present study:

> *Listening to slow tempo, instrumental background music in a virtual environment while watching a computer-animated history lesson improves memory for facts that are conveyed in this history lesson.*

If it could be established that music not only attracts students to educational virtual environments but that it also improves their memory for the content that is taught in these environments, then the usefulness of video game technologies for educational purposes could be demonstrated and the gap between entertainment and education could be narrowed. The evaluation of the impact of music and virtual environments is thus a worthwhile and essential investigation for a discussion about the usefulness of creating game-like virtual environments that teach curriculum based, real-world topics in a fun environment.

Summary

The situation of the authors' friend playing World of Warcraft and the dense musical atmosphere inspired this project and sparked the research question to determine whether the immersive power of music influences our memory and could thus be used for educational purposes. This question initiated a review of the literature on relevant topics that gave an insight into the existing body of knowledge and showed some encouraging but also some contradictory findings.

Open questions about the effect that music has on memory were also identified. Furthermore, we saw how video games and virtual environments are already used for educational purposes. Based on the findings of the literature review a hypothesis was stated that instrumental music at slow tempo and at a low pitch improves memory for facts learned in a virtual environment. In order to test the hypothesis a structured research method was applied according to the parameters of the hypothesis itself.

3

METHOD

> *That music plays an important role in the overall experience of video gaming is widely accepted, although there have been very few experimental or theoretical studies of the role of music in the perception of video game stimuli (Zehnder et al., 2006, p. 241)*

In this chapter the underlying rationale for the research design, methods, procedures, techniques and tools chosen is provided. We begin with consideration of the available methods and why some methods were appropriate and others were not (Section 3.1). We then consider an appropriate source of participants (Section 3.2), the materials to be used to construct the experimental environment (Section 3.3), the methods used for measurement (Section 3.4) and an introduction to the experimental procedure (Section 3.5). The chapter which follows the present chapter provides details about the design for two experiments.

3.1 Research Methods

The two main systems of human enquiry are qualitative and quantitative research methods and both follow very different research strategies. Where qualitative research methods take subjective human perspectives into consideration, quantitative research methods use objective numerical data (Scheurich, 2008). To explore the research question of this thesis it was decided to pursue a quantitative approach (although some qualitative data was also gathered) and design an experiment that allowed an objective analysis of the data. The reasons for this decision are discussed next.

One method for exploring a research question is to analyse library sources and other published material to discover connections or distinctions between theories or findings that were unidentified or not obvious in the original works before. However, this approach was not applicable to answer the present research question because the research into the effect of music on learning in virtual environments is very new and not much literature exists in this area. Thus, the answer to the research question could not be found directly in the existing literature but instead the findings from the existing literature served as a basis for the present investigations.

Another possibility would have been to conduct a case study or perform a series of observations. Case studies have the advantage that they thoroughly investigate the behaviour of an individual or a small group of people (Schallhorn, 2008b). However, this would have been inappropriate for the present study because we were interested in obtaining data from a sample that would also yield results relevant to a larger target population. An observation on the other hand is purely descriptive and does not allow any firm conclusions regarding cause and effect of a particular observation (Schallhorn, 2008a). Furthermore, case studies and observations can be a problem because people may behave differently when they know that they are monitored. These disadvantages were the reasons that both research methods, case study and observation, were excluded for the present investigations where 'hard data' about the number of facts that people remembered from a computer-animated history lesson was desired.

Another option to conduct our research would have been to issue questionnaires or interview people from the target population. Questionnaires have the advantage that they are comparatively cheap to develop and distribute, require little time investment because little or no hard- or software development is involved and they can gather data from a large sample of the target population (Schallhorn, 2008a). Interviews on the other hand give participants the opportunity to comment on things the researcher has not thought about, however, they require a lot of time to conduct and also the transcription of interviews is time intensive and costly. Furthermore, these research methods do not provide a controlled environment that allows the investigation of the effects of various stimuli. The present study is a causal enquiry – that is, one or more independent variables cause or affect one or more dependent outcome variables (Trochim, 2006) – and investigated the effects of changed variables on people's memory. Furthermore, it would have not been possible to change or control such variables with a 'questionnaire only' or 'interview only' approach. Thus, we believe that the best instrument to answer the research question and test the validity of the hypothesis was an experimental approach. While the experimental design included the administration of a questionnaire, the questionnaire data was collected in the context of an experiment to provide pre- and posttest data. Further discussion of the reasons for using a questionnaire and the role it played in the study are given in section 3.4. Although, as will be suggested in the final chapter, it may have been beneficial to conduct some follow-up interviews after the experiment to clarify some of the responses of individuals and assist with interpretation of the data and development of conclusions.

With an experimental method we were able to take a sample from a target population and expose each participant from this sample group to the exact same knowledge of a defined topic while changing the independent variables (i.e. the background music in the present study). Afterwards, participants could be tested for the knowledge with which they were presented and an analysis could be conducted to see under which musical influence (condition) participants remembered the most/the least of the information presented to them. Moreover, an experimental approach was chosen by others in related research areas (e.g. Boltz *et al.*, 1991; Rauscher *et al.*, 1993; Thompson *et al.*, 2001) and an experimental approach proved very useful for them. They received valuable results from their experiments and these results have not only given insights into the respective research areas but also provided a foundation for additional investigations. They are important contributions to the existing body of knowledge and to continue such contributions in these and related multi-disciplinary research areas it was decided to answer the present research question with an experimental approach as well.

However, there are two main disadvantages to an experimental approach. One disadvantage is that an artificial environment is created which does not reflect the real world in every detail. This means that participants may perform differently in an experiment scenario because an important element is missing from the real-world environment (i.e. a particular smell in their usual learning environment, comfortable working conditions, lighting, etc.). The results can thus have low external validity and it may mean that the findings cannot be generalised to populations outside the laboratory. Furthermore, there is a risk in experimental approaches that a bias for certain results can be introduced (even if unintended) by the researchers (Schallhorn, 2008a). To prevent such bias as much as possible, great care was taken to avoid possible sources of errors by conducting pilot-tests and having independent experts evaluate the musical stimuli (used in the experiments) for irregularities (see 3.3.3).

Once the decision for an experimental research method had been made, materials were developed, participants were recruited and a questionnaire was developed that would measure participants' responses to items related to identified experimental constructs. These items included biographical data, multiple-choice questions about the content, perceived level of concentration, difficulty and immersion as well as participants' prior experience with playing video games and playing a musical instrument. Furthermore, a procedure for the conduct of the experiments was established. Because the present study involved two experiments with Experiment 2 building on the results of Experiment 1, only the general methodologies will be discussed in the present chapter. Procedures and more specific methods for both experiments will be explained in chapter 4.

3.2 Participants

A study conducted by the *Entertainment Software Association* in 2008 (ESA, 2008) shows that the demography of video gamers is similar to a normal distribution. Most gamers are between 18 and 49 years of age (49%) and the 'under 18 years' and 'above 50 years' groups claim 25% and 26% of the share respectively. This shows that the largest number of people that would potentially benefit from the results of this study is represented in the 18-49 years age group. As this age range is still very wide the target population was further narrowed down to focus on those who need most support in learning activities: schoolchildren and university students.

Due to the logistical and ethical constraints that occur with schoolchildren (e.g. parents having to bring students to the lab, etc.), the decision was made to target the population of university students who could be recruited from the campus at Macquarie University. This of course is a limitation because the experiment outcomes only apply to a sub-group of the possible overall population. On the other hand this limitation to a particular sub-group is an advantage because the results are very concise for the chosen sub-group.

To recruit participants for experiments, it is quite common to access a 'participant pool' of a Psychology department. However, participants from such pools can sometimes be disinterested in a study because their participation in experiments is often a condition of their enrolment. That means they *have to* participate in a given number of experiments to gain course credits. Furthermore, the choice of such a sample would have further reduced the target population from 'University Students' to 'Psychology Students', which was undesirable. To avoid possible disinterest and reduction of target population, it was decided to advertise the experiments campus-wide through leaflets and in introductory Computing and Statistics units at Macquarie University. Through these methods of recruitment it was ensured that a broad number of people from the target population were provided the opportunity to participate in the experiments. The recruited participants were 120 undergraduate students (73 female, 47 male) from 18 to 56 years old (mean 23.6 years of age, std=5.98) of which 72 students (45 female, 27 male) participated in Experiment 1 and 48 students (28 female, 20 male) participated in Experiment 2. Four participants were identified as outliers based on their age (43, 47, 50, 56 years of age). After the literature review, age was not identified as one of the predictor variables for the current study. Thus, age information was only collected to describe our sample(s) and was not included into the analyses. In addition, since our target population were university students it was not expected to observe a normal distribution for age. To eliminate any possible bias due to these outlying observations, we have investigated their relationship to the predictors and the response variable and found that these participants were not outliers in any other dimension (i.e. the number of correctly remembered facts for these participants were neither significantly lower nor higher than those of the rest of the participants).

Participants received ten Australian dollars for approximately 30-45 minutes involvement. Further information about participants varies slightly for the two experiments and more details will be given in the respective experiment sections of chapter 4.

3.3 Materials

For the experiment at hand, several pre-conditions needed to be created in order to enable the conduct of valid investigations. Materials used for the investigations included a virtual environment that was developed to serve as a platform for associated experiments. The second major part was the preparation of the experimental stimuli. For this part suitable musical pieces were identified, presented to a group of pilot-testers and selected pieces were manipulated for use in experiments. The following sections describe the steps that were taken to create the virtual environment and the process that was used to identify suitable musical pieces. Manipulations to the musical stimuli and the reasons for these manipulations will also be explained briefly.

3.3.1 Apparatus

In the design of the present study it was important to ensure that a framework be created which allowed the measurement of the effects of music on memory in a virtual environment. To provide such a learning environment it was decided to create a computer-animated history lesson presenting the history of the Macquarie Lighthouse in Sydney. The choice of topic was based on the wide variety of different names, events and dates, which offers an excellent foundation for testing memory under different influences. This decision is supported by Randel *et al.* who state that "subject matter areas where very specific content can be targeted and objectives precisely defined" (Randel *et al.*, 1992, p. 269) benefit most from video game technology. Furthermore, the history of the Macquarie Lighthouse is, despite its importance to Australian settlement, not widely known and is thus an ideal topic for the evaluation of memory.

In order to test the hypothesis, computer game technology was used to create a '*Vir*tual *School*' (VirSchool) environment. We chose to create a non-interactive virtual environment (using video game technology), because a) it has been shown that interactivity may interfere with the experience of story (Bizzocchi *et al.*, 2003) and b) to provide better experimental control of the variables. The justification for this decision is that interactions that occur within virtual environments and video games can be highly complex and if interactivity (which is all about exploration, options and choices) had been allowed it would have been impossible to draw precise conclusions regarding the effect of background music on memory. The problem becomes obvious if we take an example of Participant A, who wanders around freely in the virtual environment and interacts with three different 'Avatars' (virtual personas). Where Participant A takes a certain route and order in which he or she receives information from different Avatars, Participant B could (and most likely would) visit these three Avatars in a different order and listen to a different piece of music at the point when the year of construction of the lighthouse (or another historical fact) was conveyed. Not only would there be a problem with the music stimulus that is not played at the same time, but also it could not be ensured that the participants would receive the historical information in sequential order. These problems were avoided by creating a computer-animated video that delivered a) the historical information in the same order to each participant and b) by playing the same music stimulus to the participants at the exact same time at which the historical facts were presented to each participant. Despite the restrictions of non-interactivity (and the resulting issues with transfer of knowledge from such a non-interactive scenario to an interactive scenario), the history lesson was created as similar as possible to a typical conversation with an Avatar in a full-feature computer-based role-playing game.

3.3.1.1 Development

Development included research into the historical background of the Macquarie Lighthouse, creation of an accurate 3D model and landscape, creation of the virtual environment in a computer game construction set, the recording of the Avatar dialogue and the screen capture of the video animations.

3.3.1.2 Historical Background

The Macquarie Lighthouse (see Figure 10) is the landmark icon on the Macquarie University Crest and, more important, it is Australia's first lighthouse. Some even say it was the first lighthouse in the southern hemisphere (Reid, 1988) in (Casey *et al.*, 2005). It is situated on the South Head peninsula of Sydney's Port Jackson harbour entrance and the lighthouse that we are looking at today is the second lighthouse that was built in almost the same spot as the first lighthouse. The history of the Macquarie Lighthouse begins with the colonisation of Australia and the arrival of the First Fleet in 1788. According to Casey and Lowe (2005), as early as 1790 a flagstaff was erected near the site where the lighthouse is located today. The flagstaff's original purpose was of course to indicate the harbour entrance to incoming ships but more important to signal the arrival of a particular ship to the colonists who were desperately awaiting supplies from England because they were running short on food.

In the years following the erection of the first flagstaff, the flagstaff was supported by a stone column (1790), upgraded (1792), rebuilt (1797) and extended by a fire beacon (between 1793 and 1805). On the 1st of January 1810 Colonel Lachlan Macquarie started his duty as Governor of New South Wales and in 1818 architect Francis Howard Greenway finished the construction of the first Macquarie Lighthouse. As early as five years after the end of the construction, repairs had to be conducted because parts of the building were falling apart. The causes for the decay were mostly attributed to low quality of the sandstone and mortar.

Figure 10: The Macquarie Lighthouse, situated on 'South Head', the southern peninsula of Sydney Harbor. The Macquarie Lighthouse is Australia's first lighthouse and its almost 200 year history serves as the background for a computer-animated history lesson and associated experiments.

Eventually, the deficiencies in construction were not tolerable anymore and from 1880 to 1883 a second lighthouse was built only 4 meters behind the old lighthouse (which was subsequently demolished). After the power supply of the lighthouse had been changed from coal-gas to kerosene in 1909, the lighthouse was connected to the main city electrical power supply in 1933. The lighthouse was automated in 1976 and demanned in 1989. Despite being demanned, it is still operational and is nowadays operated and maintained by the "Australian Maritime Safety Authority"[53]. Public tours are organised by the "Sydney Harbour Federation Trust"[54]. Further detailed historical information is supplied in

[53] Australian Maritime Safety Authority: http://www.amsa.gov.au, last accessed: 27.01.2009

[54] Sydney Harbour Federation Trust: http://www.harbourtrust.gov.au, last accessed: 27.01.2009

Appendix D, which describes the dialog that was presented to participants by the Avatar in the VirSchool history lesson.

3.3.1.3 Computer Game Construction Set

The experience of the experimental environment (the VirSchool history lesson) was created similar to a real-world scenario in which users would be talking to another person or teacher. To create such a first-person conversational experience it was decided to use the construction set of a computer role-playing game, mainly because of the outstanding game building capabilities of these construction sets. Several construction sets and virtual environments with building and scripting capabilities were evaluated (Torque[55], Neverwinter Nights[56], Second Life[57] to name a few) and it was decided to use *The Elder Scrolls Construction Set*[58] (TESCS) by Bethesda Softworks because it had the most suitable first-person camera viewpoint and because of the sophisticated dialog system which allowed not only the creation of the dialog but also features a built-in lip synchronisation for the Avatar delivering the dialog. Furthermore, custom 3D models could be imported into TESCS, which was essential for the present study as we will see in the next section.

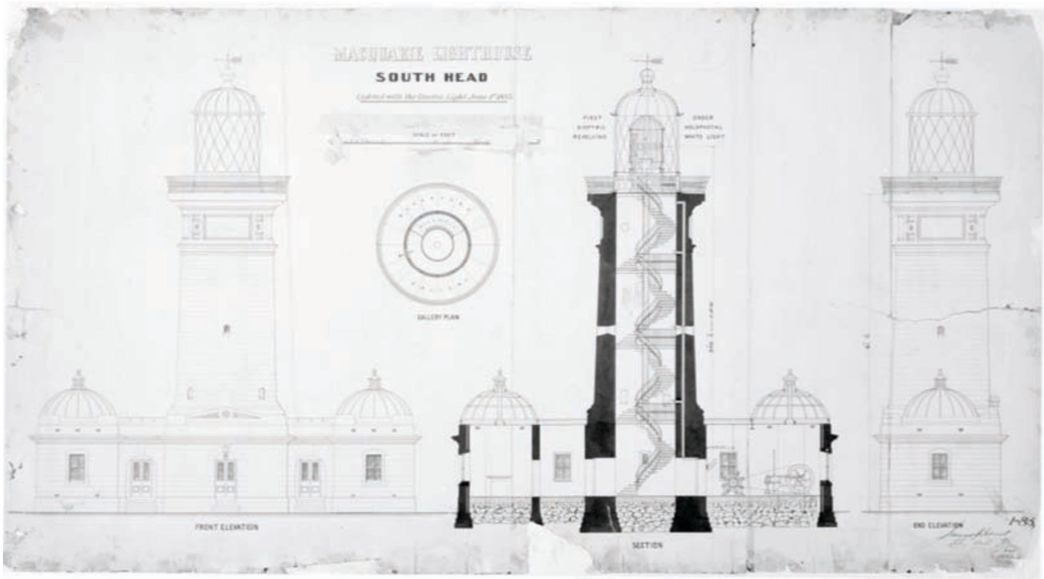
[55] Torque Game Engine: http://www.garagegames.com/, last accessed: 27.01.2009

[56] Aurora Neverwinter Toolset: http://nwn.bioware.com/builders/, last accessed: 27.01.2009

[57] Second Life: http://www.secondlife.com/, last accessed: 27.01.2009

[58] The Elder Scrolls Construction Set: http://cs.elderscrolls.com/, last accessed: 27.01.2009

3.3.1.4 Import of custom 3D model into 'The Elder Scrolls Construction Set'



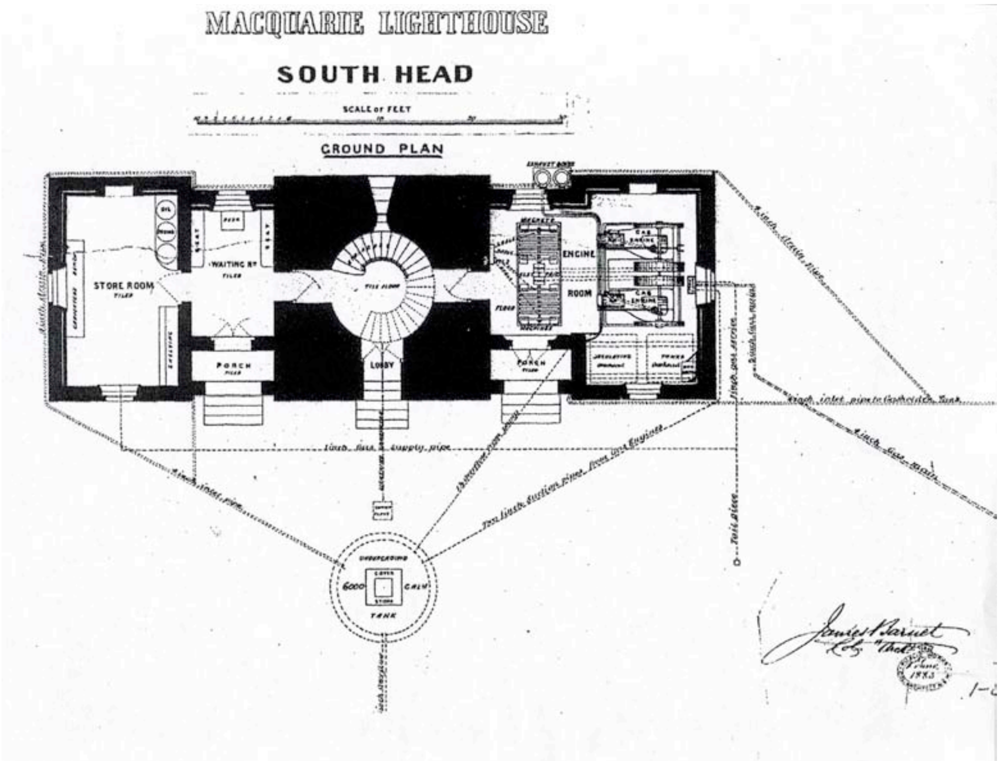


Figure 12: A top view of the Macquarie Lighthouse blueprints used for the 3D model.

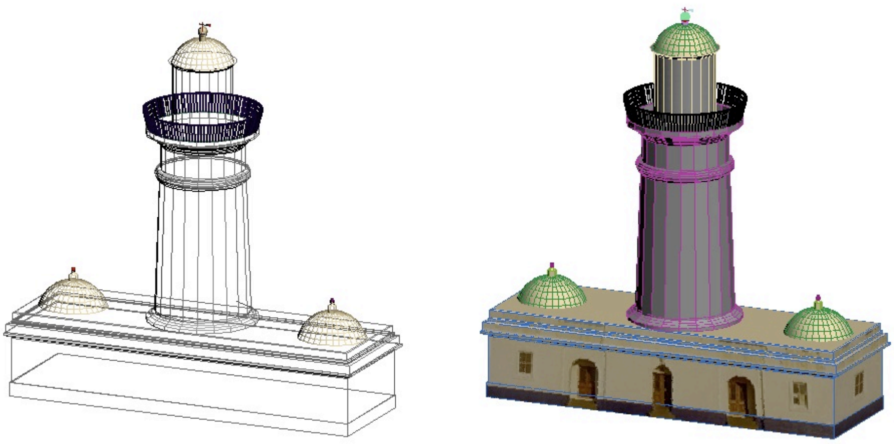


Figure 13: A 3D model of the Macquarie Lighthouse was created in 3D Studio Max.

First, a 3D wireframe model of the Macquarie Lighthouse was modelled (see Figure 13 left) and afterwards textures were added to the model (see Figure 13 right). Next, it was necessary to save the mesh in the .nif format[61] to get the model into TESCS because this is the format that TESCS uses for its 3D models. However, 3D Studio Max does not support direct export to this format and an export plug-in called Civilization IV MaxTools[62] was installed. Originally this export plug-in was developed for the computer game Civilization IV but it also works for TESCS.

Once the .nif model of the Macquarie Lighthouse had been created it was inserted into TESCS. New .nif files need to be stored in ..\Oblivion\Data\Meshes or a subfolder thereof and can then be accessed and used inside TESCS. Further technical details about the use and ex-/import of .nif files are supplied on the TESCS website[63].

3.3.1.5 Creation of Landscape

After the 3D model of the Macquarie Lighthouse had been created and inserted into TESCS, the surrounding landscape was reproduced as accurately as possible. This was achieved with the help of a survey map also supplied by the "Sydney Harbour Federation Trust". However, the survey map as seen in Figure 14 was too cluttered with information and a simplified version (see Figure 15) was produced to serve as a guide for the creation of the landscape in TESCS.

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[61] NifTools: http://niftools.sourceforge.net/wiki/Nif_Format, last accessed: 18.03.2009

[62] Civilization IV MaxTools: http://www.civfanatics.net/downloads/civ4/utility/CivilizationIV-MaxTools-v6.zip, last accessed: 27.01.2009

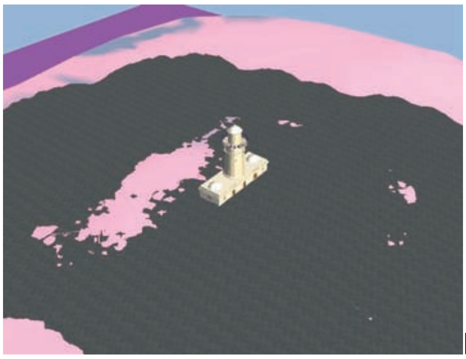
[63] TESCS: http://cs.elderscrolls.com/constwiki/index.php/NIF_Files; and

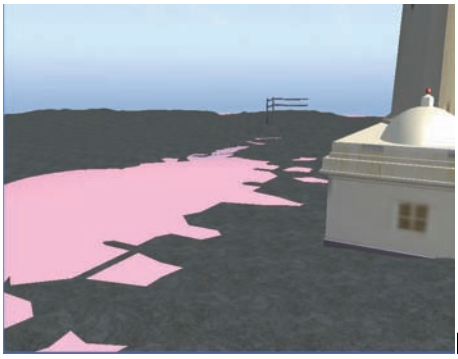
http://cs.elderscrolls.com/constwiki/index.php/Working_With_Nifs_101_:_An_Introduction, last accessed: 27.01.2009

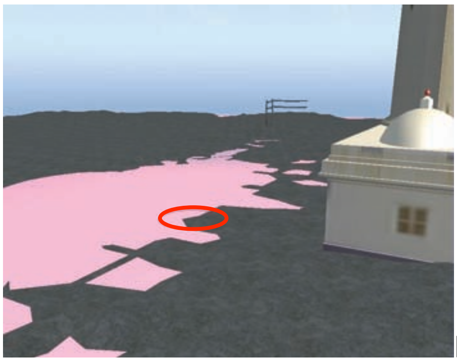
Figure 14: A survey map with accurate position and height information. Source: (SHFT, 2006)

Figure 15: A simplified version of the survey map was used for the creation of a height model that served as a guide to create an accurate representation of the landscape surrounding the Macquarie Lighthouse.

The simplified survey map was used to create a height model of the area in 3D Studio Max. This height model was also imported into TESCS (see pink landscape breaking through dark-green texture in Figure 16) and subsequently, the landscape surrounding the Macquarie Lighthouse was adjusted to fit the underlying height model. Figure 17 shows a close-up of the height model (pink), the landscape (dark-green 'grass' texture) and the Macquarie Lighthouse (right).







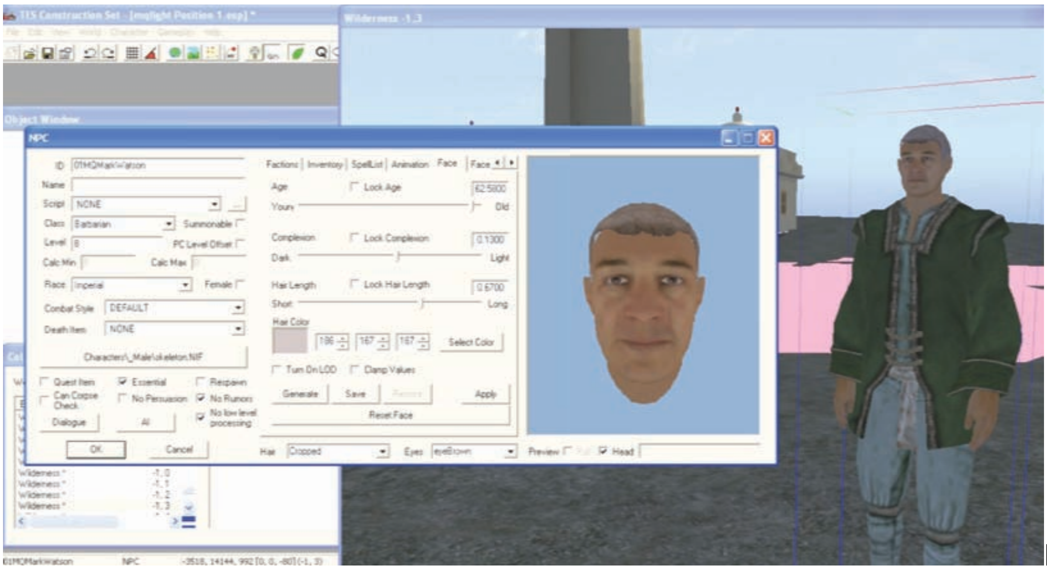
[illegible]

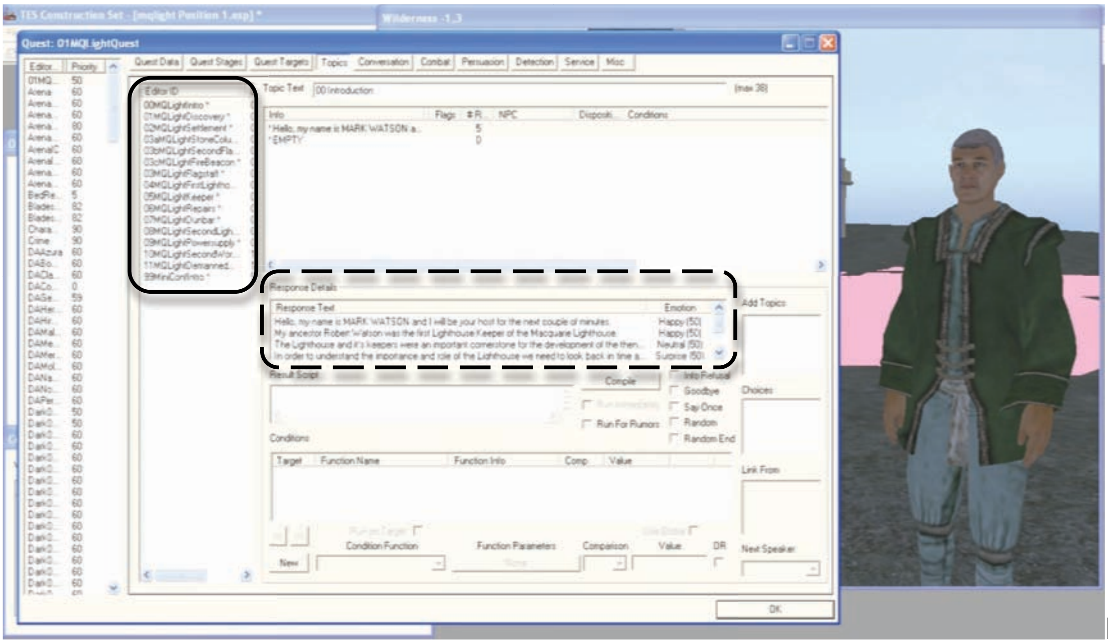
[illegible]

[illegible]

3.3.1.6 Character and Dialog Development

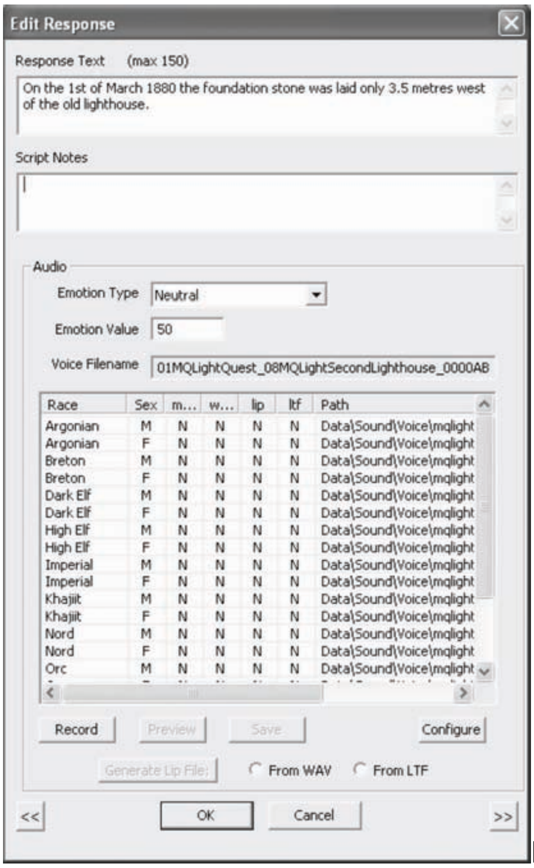
[illegible]


NPC
ID
Name
Script
Class
Level
Race
Combat Style
Death Item
Age
Lock Age
Young
Old
Complexion
Lock Complexion
Dark
Light
Hair Length
Lock Hair Length
Short
Long
Hair Color
Select Color
Generate
Save
Apply
Reset Face
OK
Cancel
Hair
Cropped
Eyes
Head
Wilderness -1,3


Quest: 01MQLightQuest
Quest Data
Quest Stages
Quest Targets
Topics
Conversation
Combat
Persuasion
Detection
Service
Misc
Topic Text
Response Details
Response Text
Conditions
OK

(~ 1/10th of the size of the .wav file), yet the loss of quality (due to compression) is not important anymore at this stage because the human ear is tricked by the psycho-acoustic compression method of the MP3 format and the signal does not need to have the same high quality which was necessary for the lip synchronisation process. Figure 23 shows an example of one of the sentences about the construction of the second lighthouse that was recorded, synched to the lip movements of the Avatar and then linked to the smaller size .mp3 file for use in the VirSchool history lesson. Both audio files, the .wav and the .mp3, have to be placed in the folder that corresponds to the Avatar that was chosen (Imperial Male in our case). For the present project this folder was ..\Oblivion\Data\Sound\Voice\mqlight.esp\Imperial\M. These methods ensure that *'what you read (subtitles) is what you hear (spoken text) and what you see (lip movements of the Avatar)'*. The lip-synching method is an extremely powerful tool of TESCS and is described in detail on the website of TESCS[65].

[65] http://cs.elderscrolls.com/constwiki/index.php/Audio_Settings_For_Dialogue_Video_Tutorial, last accessed: 27.01.2009

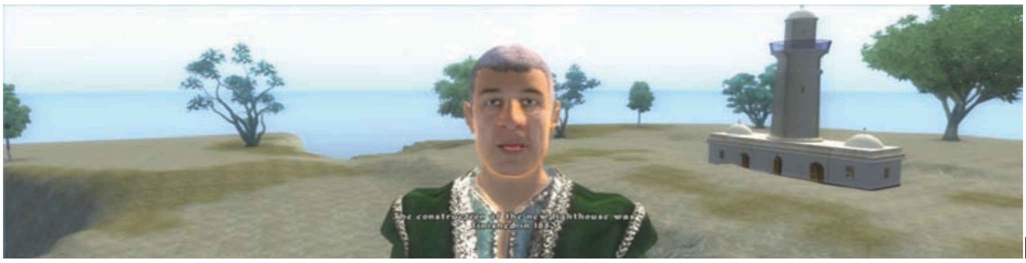


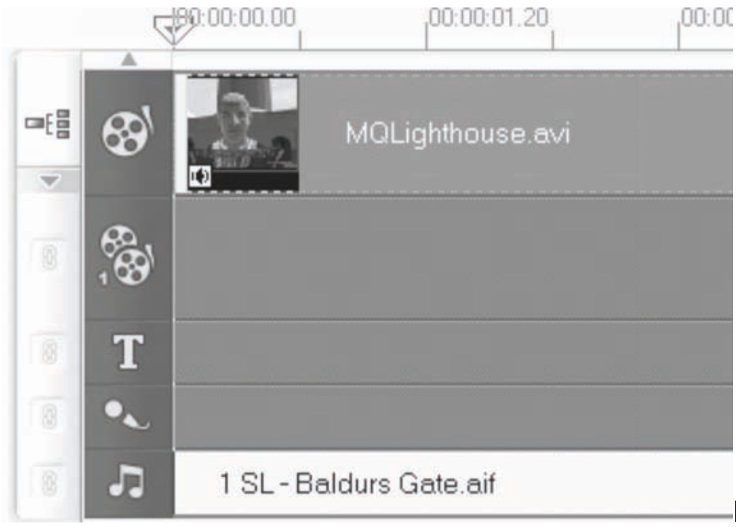
[illegible]

3.3.1.7 Video

[illegible]

[66] Fraps: http://www.fraps.com/, last accessed: 29.01.2009


construction of the new lighthouse was


00:00:00.00
00:00:01.20
00:00
MQLighthouse.avi
1 SL - Baldurs Gate.aif

3.3.1.8 Display Systems

In Experiment 1, a portable version of Silicon Graphics Inc.'s Reality Center (SGI, 2009) was used (see Figure 26) and for Experiment 2, a 3-monitor display system (see Figure 27) was also used as a second experiment environment apart from the Reality Center. The reason for using this second display system was an equipment failure of the Reality Center during Experiment 2 and the details and implications of this will be explained in section 4.2. We decided not to use a Head-Mounted Display (HMD) in our experiments because of the complicated setup that is required for each participant.

Figure 26: The Reality Center - An immersive projection screen with a 150 Degree 'Field of view'.

SGI's Reality Center consists of 3 projectors that display the virtual environment onto a semi-cylindrical screen canvas. The user is positioned slightly off-centre towards the canvas to allow a 150° field of view (FOV) which simulates almost the maximum of 180° of humans FOV. Through this setup the virtual environment occupies most of the user's visual field and the user gets immersed in the virtual environment.

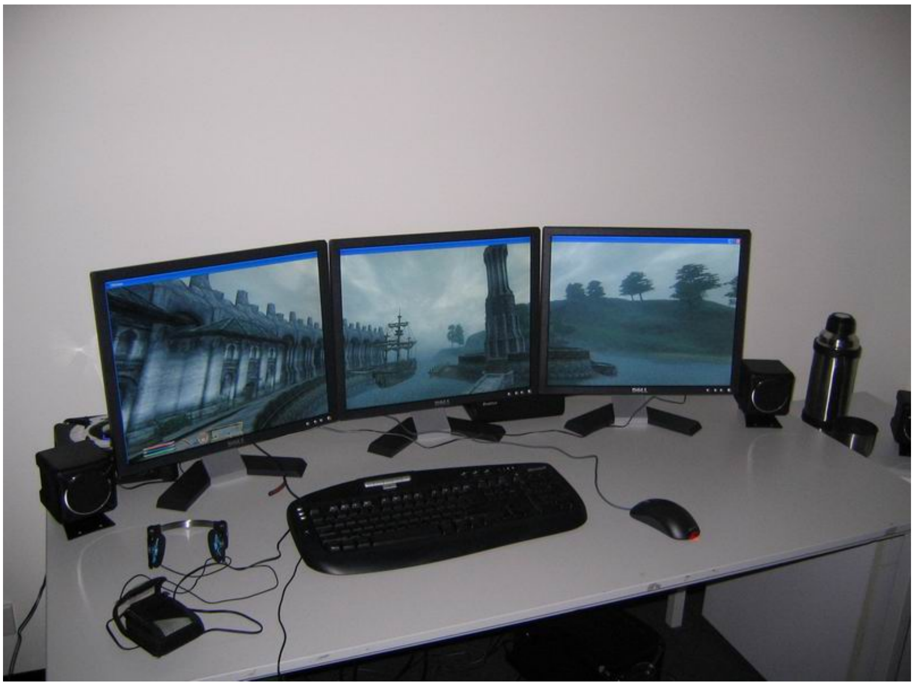


Figure 27: A scene from the original computer game 'The Elder Scrolls IV – Oblivion' running on three monitors.

Figure 27 shows the 3-monitor display system that was used with half of the participants in Experiment 2 (i.e. it was not used in Experiment 1). The display system shows a scene from the original computer game 'The Elder Scrolls IV - Oblivion' instead of the VirSchool history lesson because the photo was taken at an earlier stage of development when a solution was sought (and found) to drive the three displays and the three projectors of the Reality Center.

The solution that was found and put in place during the above-mentioned development stage is a Matrox TripleHead2Go external video signal splitter. This device was able to supply both display systems with the 3072x768 wide screen video signal and the concept of this video splitter is shown in Figure 28. It is

mm 0I – sV r Sn a sVr S om n S t m T

mm 73 – f Snys SF sf n S St nVt S om n S t m yn nEn SF
C s t r t a st SES Sn y nt r SEn SFC S r s Sr St S t e amSnEr e S
St nVs t r C n r r t E r ss r a t r T

3.3.2 Stimuli

In the literature review we discussed a number of studies that investigated the effect of music on different cognitive abilities. From these studies we extracted the relevant findings and combined these in order to create the stimuli for the present study. Rauscher *et al*. (1993), for example, acknowledged that the results of their experiments were only conclusive for "one musical sample of one composer" and because they suggested that "various other compositions and musical styles should also be examined" (Rauscher *et al.*, 1993, p. 611), initially we planned to compare a classical music stimulus with stimuli from the pop/rock, didgeridoo and nature sound genres. Furthermore, it was intended to compare vocalised music with instrumental music (i.e. to have lyrics sung over a classical piece of music and compare results of the vocalised version and the devocalised/instrumental version). However, it soon became apparent that the comparison of these genres would introduce too many independent variables (timbre, rhythm, style, etc.) to conduct a controlled experiment. Consequently, it was decided to use only one musical genre and investigate whether changes in some of the parameters of this genre show different effects on memory.

Computer role-playing game music was selected for use in the present study because this genre combines two main elements of this study – music and video games. The music in computer role-playing games is ambient style instrumental music (i.e. without vocals) and it is similar to classical music as was used in the studies mentioned above (Allen *et al.*, 1994; McFarland *et al.*, 1988; North *et al.*, 1999; Pring *et al.*, 1994; Rauscher *et al.*, 1993; Thompson *et al.*, 2001) Furthermore, the fact that all tracks that were reviewed from the soundtracks of the four video games used in Experiment 1 (see section 3.3.3) were instrumental suggests that this musical style (that of computer role-playing games) may be instrumental in most of the computer role-playing games. Since instrumental music has been shown (Allen *et al.*, 1994; Hass *et al.*, 1985; McFarland *et al.*, 1988), to avoid intrahemispheric and interhemispheric competition in and between the brain halves and thus benefits certain cognitive processes in other experiments there was a likelihood that this musical style may offer benefits to memory processes as well. Moreover, since the construction set of a computer role-playing game (The Elder Scrolls IV - Oblivion) was used to create the virtual environment for the VirSchool history lesson and because computer role-playing games are the type of virtual environment which requires (quasi-) conversation with the Non-Player Characters (NPC) and memorisation of a great number of names, places and facts, it was important to use music from this genre.

However, it was unclear whether changes in tempo and pitch of such musical stimuli from the computer role-playing game genre would have a similar effect to the one observed by Ilie and Thompson (2006). Details of the tempo and pitch manipulations that were applied to create different experiment stimuli are given in Chapter 4 – Experiment 1.

3.3.3 Pilot-Tests

In order to gain a somewhat representative sample of music from the computer role-playing game (RPG) genre, the soundtracks from four contemporary RPG's, namely 'Oblivion'[67], 'Baldur's Gate'[68], 'World of Warcraft'[69] and 'Icewind Dale'[70], were chosen as source materials for musical pieces (tracks) that would subsequently be used as musical stimuli. These games were selected because they are all successful computer RPG’s and their soundtracks were either sold separately or are accessible from the installation medium or folder on the harddrive (some other games use proprietary sound formats that could not be used for extraction of musical stimuli).

From each soundtrack of each game three tracks were pre-selected by the author according to the following criteria.

1. One track was selected that appeared to the author to be suitable for the VirSchool history lesson.

2. One track was selected that appeared to the author to be unsuitable for the VirSchool history lesson.

3. One track was selected that the author was of divided opinion about whether it was suitable or unsuitable for the VirSchool history lesson.

[67] http://www.elderscrolls.com/, last accessed: 24.12.2008

[68] http://www.bioware.com/games/baldurs_gate/, last accessed: 24.12.2008

[69] http://www.worldofwarcraft.com/, last accessed: 24.12.2008

[70] http://www.blackisle.com/ or http://www.mobygames.com/game/icewind-dale/, last accessed: 24.12.2008

The author was aware of the possible subjective influences of this pre-selection process and great care was taken to be as objective as possible. The ratings given by the author were as follows:

Table 1: The preselected tracks as rated by the author before presentation to the pilot-testers

Track Name	Suitable	Unsuitable	Divided
Baldurs Gate - The Friendly Arms Inn	X		
Baldurs Gate - Gorion's Battle		X	
Baldurs Gate - Night On The Plains			X
Icewind Dale - Easthaven in Peace	X		
Icewind Dale - Belhifet's Doom		X	
Icewind Dale - Marketh's Palace			X
Oblivion - Town_03	X		
Oblivion - Dungeon_02		X	
Oblivion - Atmosphere_07			X
World of Warcraft - Temple	X		
World of Warcraft - Duskwood		X	
World of Warcraft - Elwynn Forest			X
Braveheart - The Secret Wedding		X	
Madonna - Like a Virgin		X	
The Lord of the Rings - Return of the King Anduril		X	

The three pre-selected tracks from four different RPG's were subsequently presented to a group of six pilot-testers who were recruited from the Department of Computing at Macquarie University. All pilot-testers have extensive experience with RPG's and the embedded soundtracks. In addition to the 12 tracks from the four soundtracks (three from each soundtrack), two tracks from well-known movies (The Lord of the Rings, Braveheart) and one track from the rock/pop genre (Madonna – Like a Virgin) were added as control stimuli. The control stimuli were included to confirm that pilot-testers understood the task at hand and were able to clearly distinguish between tracks that were suitable for the RPG genre and tracks that were not. The pilot-testers were asked to rank the musical pieces on a scale from 1 to 5 as being

a) not representative (1) or representative (5) for the RPG genre

and

b) not suitable (1) or suitable (5) for the VirSchool history lesson

Tracks that scored the highest overall value in both categories were selected for further experiments. None of the tracks from the control stimuli was selected, because their origin did not lie within the genre of computer RPG (Note: None of the tracks from the control stimuli scored as high as the highest scoring tracks from the RPG genre).

The highest scoring tracks from the RPG genre were:

- Oblivion **town_03**.mp3
  (to be found in the install directory of the game, e.g. C:/Program Files/Bethesda Softworks/Oblivion/ Data/Music/Public/)

- Baldur's Gate **The Friendly Arms Inn**
  (to be found on the Soundtrack CD (Music by Michael Hoenig))

- World of Warcraft **Temple (Intro Cue)**
  (to be found on the Soundtrack CD (Blizzard Entertainment))

- Icewind Dale **Easthaven In Peace**
  (to be found on the Soundtrack CD (included in "Icewind Dale – The Ultimate Collection"))

The pitch and tempo of these four tracks were then manipulated and compared with each other in regards to their effect on memory. A 'No Music' condition was used as a baseline. Further details about manipulation and the experiment design are given in the experiment chapters.

3.4 Measures

The method used for the present thesis was to collect data from the target population by means of questionnaires in a pretest, experiment, posttest design. This decision was based on the fact that data collection via questionnaires is less invasive than for example measuring participants' physiological or mental responses by using biofeedback or EEG (Electroencephalography) measures. Also questionnaires are a good source of quantitative data as opposed to, for example, interviewing participants after the experiment. Questionnaires provide systematic, representative, objective and quantifiable data (Isaac *et al.*, 1985, p. 128) However, questionnaires only have a defined set of questions and do not allow probing behind the question to ask *why* a certain number has been assigned by the participant. For example, participants might reveal extra information in an interview because they have the ability to comment directly and without being restricted to the set of questions. This extra information might give insight into areas that the researchers did not consider in a questionnaire. In some studies interpretation of the responses might be very important and if there is no opportunity to question the participant with their reason the conclusions drawn by the study will be subject to the biases of the investigator and be open to (mis-)interpretation. For example, if a respondent selects the degree to which they agree or disagree with a statement, it may not be clear why that choice was made. In the present experiments the focus was on how many of the facts about the lighthouse were remembered correctly and thus this is not a major issue. Therefore, for the present experiments it was decided to use questionnaires in order to reduce investigation time and to collect quantitative data.

The questionnaire used for the present study was grouped into the following four parts.

- Part A collected general information about participants such as age, gender, first/second language, etc.
- Part B of the questionnaire used the multiple-choice format for questions about the topic presented in the experiment.
- Part C included questions about perceived level of concentration, perceived level of difficulty of the VirSchool history lesson, feelings about the background music and perceived level of immersion. A Likert scale was used for this part of the questionnaire (see below for explanation).
- Part D used ordinal and nominal scales to record participants' previous experience with playing video games and playing a musical instrument.

The measurement methods used in parts A, B and D were chosen because they limit answers to a predefined set of possible responses. This allows a categorisation of the results, which can be analysed most efficiently in this way rather than extracting meaning from freeform answers.

For part C it was decided to use a Likert scale of which the original version was developed by Rensis Likert in 1932 (Likert, 1932). Likert scales are frequently used in studies on interaction in virtual environments (Gardner *et al.*, 2007, p. 439), however, Gardner *et al.* point out (*ibid.*) that Likert scale style questionnaires can have a tendency to 'lump' in certain parts if the questions are phrased ambiguously. For example, if a Likert scale is used for an either/or question (e.g. "Do you think that this virtual environment was a useful learning tool?") the answers tend to lump at the two extremes ('Not at all', 'Completely') creating a U-shaped response graph. Several of these questions were unintentionally used in the questionnaire for Experiment 1 because only after the conduct of Experiment 1 did the author find out about these possible issues.

For Experiment 2, great care was taken in (re-) phrasing the questions and Gardner was consulted in person to improve the questionnaire and reduce ambiguities as much as possible.

Some questions in Part C of the questionnaires for both experiments investigated the effect of immersion and presence on memory. There is evidence (Mania *et al.*, 2001; Slater *et al.*, 1997), that a higher level of immersion leads to an increased feeling of presence in a virtual environment. These feelings can be influenced by the visual and the auditory sense. However, as was mentioned before (section 2.2), the insights from this research area are controversial and at least for the visual channel "results relating measures of presence in VE [Virtual Environments] to learning and performance in the VE and in the real world have been mixed" (Witmer *et al.*, 1998). There is further evidence that an increased feeling of presence does not lead to a higher retention or knowledge transfer rate (Moreno *et al.*, 2004).

Despite the lack of clear evidence of the benefits of increased immersion and presence, research is ongoing in this area and apart from the above mentioned visual immersion there are other aspects that increase immersion. Sound and music are two of these aspects and it may be because "the success and popularity of this franchise [using music creatively in video games] is definitive evidence that players find the creative linking of music and game play to be very compelling" (Nelson *et al.*, 2007) that researchers are investigating new ways to increase the feelings of immersion and presence in virtual environments through personalised sound effects. For example, Dekker and Champion (2007) describe how biofeedback signals of the players can be used to change the game environment according to how players feel. Through this technique a higher level of immersion into the Virtual Environments is achieved and participants "seemed to be more engaged in the [biometrically] enhanced version especially when sounds were played" (Dekker *et al.*, 2007, p. 557). This observation is supported by Zehnder and Lipscomb (2006) who evaluated the role of music on immersion in a video game scenario. They state that "music plays a significant part in creating a sense of immersion in the game" (Zehnder *et al.*, 2006, p. 243) and that "music also serves an important role in the cultivation of the senses of perceptual or psychological presence in the video game" (Zehnder *et al.*, 2006, p. 249). Their experiments involved three scenarios – video game with music, video game without music and music only. The results from their experiments show that "statistically significant differences clearly emerge as a result of the presence of music". Unfortunately, they do not give any further details because "a detailed discussion of these empirical results is beyond the scope of the present chapter" (Zehnder *et al.*, 2006, p. 254). However, Zehnder and Lipscomb state that research of the relationship between music, video games, and the feeling of presence and immersion into a virtual environment is not sufficiently researched at this point in time. They say, "both players and [...] those involved in creating the games share the belief that the presence of music enhances the video game experience. However, our review of related literature revealed no experimental studies into this relationship" (Zehnder *et al.*, 2006, p. 251). Moreover, Moreno and Mayer summarise research in the immersion and presence area by saying that "the major limitation of the immersion hypothesis is that the concept of physical presence is somewhat fuzzy and there is a lack of consensus on a valid instrument for measuring it" (Moreno *et al.*, 2004, p. 166). Discussion and research in the area of immersion and presence is ongoing and despite the 'fuzzyness' (Moreno *et al.*, 2004, p. 166) and although immersion and presence were not a main interest of the present study, several questions about immersion and presence were included in the questionnaires in order to contribute to the knowledge in this research area. Our findings will be discussed in the results section of Experiment 2.

Cybersickness occurs when there is a conflict or mismatch between visual cues that give the brain the impression that the participant is moving around and vestibular/proprioception cues that tell the brain that the participant is stationary (Redfern *et al.*, 2001; Sharples *et al.*, 2008). However, cybersickness is most often observed in fast moving immersive virtual environments (Kim *et al.*, 2005) and because the VirSchool history lesson is a static virtual environment, cybersickness was not a major concern of this study. Consequently, only one question about cybersickness was asked in the questionnaire to make sure that participants were not suffering from any discomfort.

3.5 Procedure

The procedures for Experiment 1 included the computer-animated VirSchool history lesson, the Reality Center and musical stimuli. Experiment 2 additionally used a 3-monitor display system, an adapted experiment design and an adapted questionnaire. Because the description of these procedures is clearer if explained separately for each experiment, they are included in the following chapter together with the results and analysis for each experiment.

Summary

In the present chapter we described the different research methods that are commonly used to investigate a research question. Moreover, we gave reasons why we chose an experimental approach for our investigations and explained why other research methods were excluded. We also described the target population and recruitment of experiment participants as well as the participant sample group itself. We supplied the historical background and discussed the materials that were developed to create the 3D computer-animated VirSchool history lesson about the history of the Macquarie Lighthouse. The different parts of the development included the modelling of the lighthouse, import of the 3D model into TESCS, construction of the landscape surrounding the lighthouse in TESCS, creation of the Avatar itself and the written and spoken dialog as well as the recording of different versions of the videos of the VirSchool history lesson. Additionally, we elaborated how immersion and presence might be linked to learning. Finally, we showed how and why experimental stimuli were selected and which measures were used to investigate the effect of these different stimuli on memory for facts in virtual environments. In the next chapter we will look at the experiments that were conducted with the developed materials and describe some of the elements of the present chapter in more detail.

4

Experiments

This chapter is divided into two parts, Experiment 1 and Experiment 2. For Experiment 1 we manipulated tempo and pitch of different computer game soundtracks to see how these musical attributes influenced participants' memory for the historical facts of the Macquarie Lighthouse. We describe the experiment design, the creation of the musical stimuli, participant data and the procedure. We analyse and interpret the results of Experiment 1, which were used for a follow-up experiment. This follow-up experiment (Experiment 2) investigated the significant results of Experiment 1 and reduced the variance due to different pitch and tempo by using the most beneficial combination of soundtrack, tempo and pitch from Experiment 1. Furthermore, Experiment 2 investigated how two different display systems influenced participants' remembrance of historical facts.

4.1 Experiment 1

Experiment 1 was conducted using the Reality Center (see Figure 26) for which six versions of the VirSchool history lesson were created. Five versions featured variations of tempo and pitch and one version was created earlier (see section 3.3.1.7) without background music. In the following sections we will describe how the stimuli were chosen and manipulated and we will describe the participants of these two experiments. Furthermore, we will describe the measures that were used for the data collection and explain the experiment procedure. Finally, we will present the results and discuss these at the end of this chapter.

4.1.1 Stimuli

As reported earlier (see 2.4.1), two musical attributes that have powerful effects on emotion and mood are tempo and pitch (Thompson *et al.*, 2001). In order to investigate whether variations of these two attributes also have an effect on learning, the pieces selected from the pilot-tests were manipulated in tempo and pitch according to Ilie & Thompson's earlier work (Ilie *et al.*, 2006) in which they reduced tempo by 21% and increased tempo by 26%. Pitch was lowered and increased by 2 semitones respectively. The rationales for these values are based on pilot tests that Ilie and Thompson performed (Thompson, W. F., personal conversation). In the pilot tests they evaluated the effects of changing pitch on the naturalness of the stimuli. If the pitch of music or speech was raised too much, the resulting stimuli sounded artificial. Thus, their aim was to change pitch as much as possible without generating artificial sounding stimuli. Ilie and Thompson found that an increase/decrease of 3 semitones resulted in artificial sounding stimuli and therefore changed the pitch by only 2 semitones, which did not result in any significant changes in the naturalness of speech and music. Because pitch is logarithmically related to frequency, tempo changes were adjusted according to the amount that the two semitone pitch change would equate to in a linear system (which tempo is). Thus, the difference between the high and low pitch conditions (2 semitones) was physically equivalent to the changes in tempo (-21% / +26%).

Figure 31 shows a 3x3 matrix according to which musical pieces were manipulated and subsequently used as the experimental conditions. Tempo manipulations are displayed horizontally (Slow (reduced by 21%), Medium (original tempo, unaltered), Fast (increased by 26%)). Pitch manipulations are displayed vertically (Low (reduced by 2 semitones), Medium (original pitch, unaltered) High (increased by 2 semitones)). Medium in both cases indicates that the musical piece remained at its original tempo and pitch.

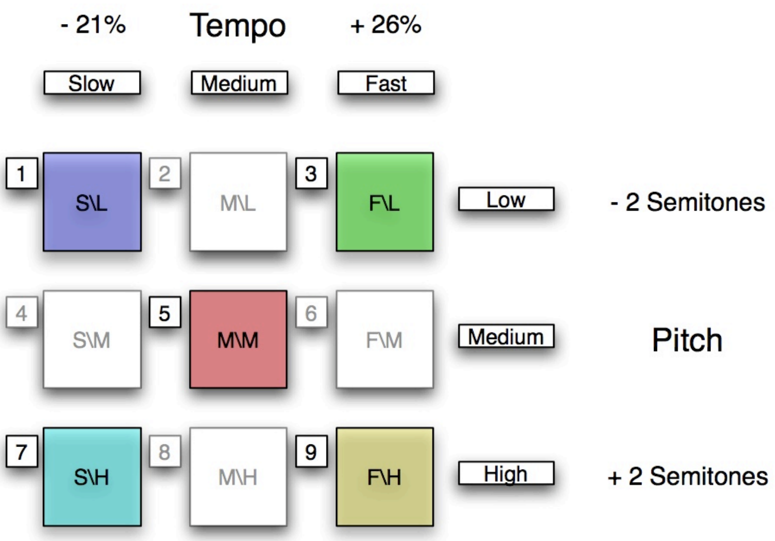


Figure 31: The musical stimuli for Experiment 1 were created according to a 3x3 Tempo and Pitch Matrix. Only the coloured resulting stimuli (1, 3, 5, 7, 9) were used for the experiment.

The above design is a balanced 2x2 design with slow/fast tempo and low/high pitch. However, a medium overall condition (see Figure 31, Experiment Condition 5, medium tempo/medium pitch) was included with the medium value for tempo and pitch. The medium values for the different tracks were in effect the original tempo and pitch of each track. This 2x2 design with an added medium overall condition allowed the use of a smaller number of participants while reducing laboratory time.

The following five combinations of tempo and pitch were used during experiments (colour-coded in Figure 31, Figure 32 and Figure 33).

- Experiment Condition 1: S\L – Slow Tempo\Low Pitch Purple
- Experiment Condition 3: F\L – Fast Tempo\Low Pitch Green
- Experiment Condition 5: M\M – Medium Tempo\ Medium Pitch (Tempo and Pitch unaltered) Red
- Experiment Condition 7: S\H – Slow Tempo\High Pitch Turquoise
- Experiment Condition 9: F\H – Fast Tempo\High Pitch Light Brown

Figure 32 shows how each of the five manipulations were performed on the four tracks selected from the pilot-tests ('town_03' from Oblivion, 'The friendly arms inn' from Baldur's Gate, 'Temple' from World of Warcraft, 'Easthaven in Peace' from Icewind Dale). A control group (Condition 10) was assigned to the 'No Music' condition (created earlier, see section 3.3.1.7). In the following paragraphs and chapters we will refer to the 'with background music' conditions as 'Music' and to the 'no background music' condition as 'No Music'. 'No Music' in this context means that participants still heard the voice of the Avatar, they just did not hear any music in the background of the audio narration.

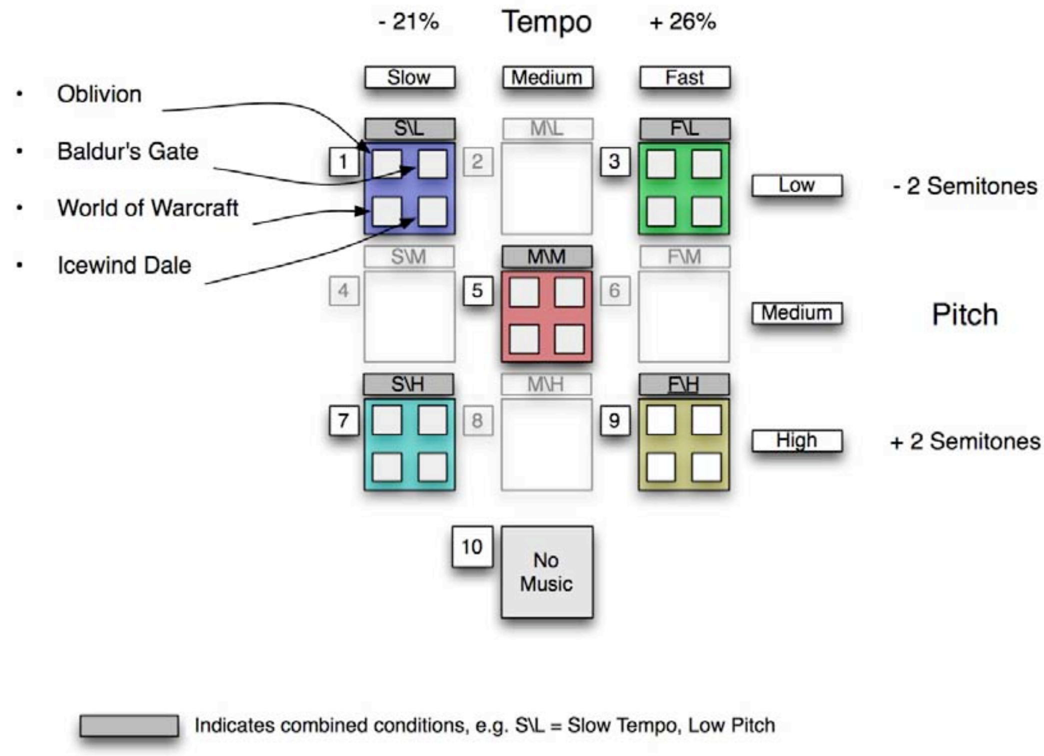


Figure 32: An improved diagram of the tempo and pitch manipulations. The four squares inside the bigger coloured rectangles represent the four musical pieces from the different computer game soundtracks (Oblivion, Baldur's Gate, World of Warcraft, Icewind Dale). These computer game soundtracks were manipulated according to the indicated tempo and pitch criteria. A control group received a 'No Music' condition with only the audio narration of the Avatar and without background music.

The manipulations were accomplished using an Apple Macbook Pro and Ableton Live 6.0.7, a professional DAW (Digital Audio Workstation) software that allows convenient and high quality tempo and pitch manipulations. In order to reduce artefacts that could occur from processing the tempo and pitch manipulations one after the other, tempo and pitch of the tracks were manipulated at the same time. Thus, only one manipulation process was conducted rather than two separate processes. Table 2 shows the absolute and relative tempo of the tracks after manipulation. For a discussion on the difference between absolute and relative tempo see section 4.2.1

Table 2: Absolute tempo in beats per minute (BPM) and relative tempo after manipulation (S/M/F=Slow, Medium, Fast).

Tempo	S	M	F
Oblivion ->	92	116	146
Bal Gate ->	82	104	130
Wow ->	111	142	174
IWD ->	81	95	114

The resulting stimuli were presented to three music experts[71] from the Department of Contemporary Music Studies at Macquarie University. None of the experts found irritating distortions or could identify the manipulations.

Following the tempo and pitch manipulations, the 20 resulting stimuli (five tempo/pitch combinations * four music tracks) were arranged into five 'Tempo/Pitch Combination' categories (colour-coded in Figure 33) and an equal number of participants were assigned to each Tempo/Pitch category (twelve participants) and each stimulus within these categories (three participants). Twelve participants were assigned to the control group in the 'No Music' condition.

The described design is called a 'Between Subjects Design', meaning that each participant received only one stimulus and results of each participant are combined with those of other participants in the same group. Results are then averaged and compared with the averaged results of other groups. Instead of allocating each participant to one stimulus, we could have exposed all participants to each stimulus (five music and one no music) within the 10:59 minutes of the Macquarie Lighthouse history lesson (the overall length was 11:38 minutes, however, of this 43 seconds were introduction where no stimulus

[71] Dr Mark Evans - Head of Department (of Contemporary Music Studies)

Sarah Keith – Associate Lecturer

Bojan Neskovic – Master of Recording Arts Student was presented). However, as well as the fact that 1:50 minutes for each stimulus would have possibly been too little exposure to assess any significant effect of a stimulus, most likely the participants could have been confused or disturbed due to the constant change of the stimulus (i.e. changes in tempo and pitch). In addition, the VirSchool history lesson sometimes had longer explanatory passages with background information and passages where the facts were closer together. Therefore, it would have been complicated to fit an equal amount of information into six separate parts from 29 facts that were included in the questionnaire.

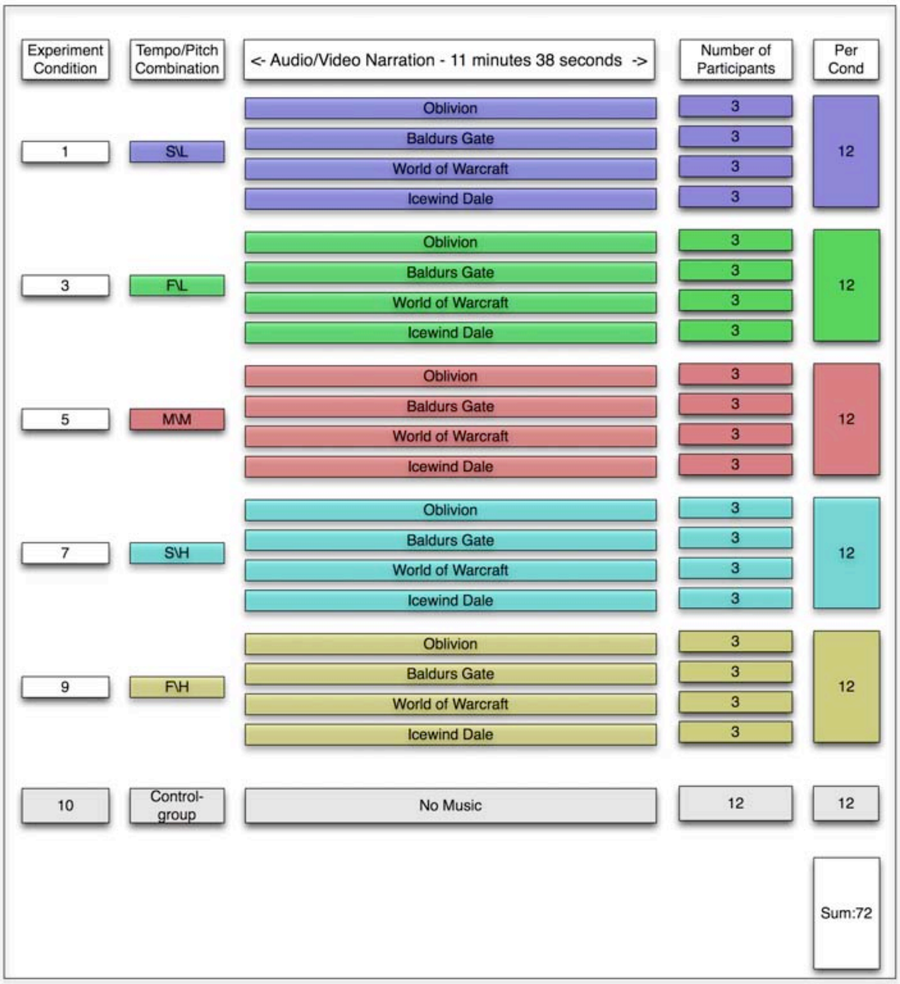


Figure 33: The stimuli (experiment conditions 1, 3, 5, 7, 9, 10) and the associated number of participants for each stimulus and category/condition.

4.1.2 Participants

The participants were 72 undergraduate students (45 female, 27 male) from 19 to 56 years old (mean 24.2 years of age, std=6.68). The students were recruited by advertisement on campus and from introductory statistics and computing classes at Macquarie University, Sydney. Participants received 10 Australian dollars for their involvement. 15 participants indicated English as their first language while 57 participants answered that English was their 'second or other' language.

4.1.3 Measures

Participants completed a questionnaire that gathered data from 4 different categories – biographical data, memory of facts from the VirSchool history lesson, participants' feeling of immersion into the virtual environment and participants' previous experiences with computer games and music. The following list shows a representative overview of the questions from each category that was asked in the questionnaire. The complete questionnaire is available in Appendix C as indicated in the respective sections.

Participants answered

- 4 questions about their biographical data (e.g. Age, Gender, First Language). For the complete set of questions refer to Appendix C, p. 222.

- 29 questions about the history of the Macquarie Lighthouse as covered in the VirSchool history lesson (e.g. "What was the name of the first lighthouse keeper?", "In which year was the first lighthouse built?", "How many people were stationed at the lighthouse?"). For the complete set of questions refer to Appendix C, p. 223.

- 27 questions about participants' preferences in regards to different parts of the video narration (e.g. "Do you think that this virtual environment was a useful learning tool?", "Did you like the music you were listening to?") as well as some questions about the immersiveness of the video narration (e.g. "How well were you concentrating?", "How much did you lose track of time?"). For the complete set of questions refer to Appendix C, p. 231. Participants who were in the 'No Music' condition received a version of the questionnaire without questions C 11 to C 18 because these were not applicable.

- 5 questions about participants' prior experience with music and computer/console games (e.g. "How many years have you been playing computer/console games?", "How many years have you been playing a musical instrument?"). For the complete set of questions refer to Appendix C, p. 235.

4.1.4 Procedure

Experiment 1 consisted of three stages: pretest, experiment and posttest. Figure 34 shows the physical setup of the experiment room with the participant's location within the room for each stage of the experiment.

1. Pretest Stage: Participants started the experiment by answering a short pretest questionnaire (see Appendix C, p. 222) about biographical data (see position 1 in Figure 34).

2. Experiment Stage: One participant watched the VirSchool history lesson about the Macquarie Lighthouse (10:59 minutes) at a time. Participants were asked to sit in the centre of the display system (see position 2 in Figure 34) where they watched and listened to the stimuli (described in Section 4.1.1). The audio part of the VirSchool history lesson was presented through a pair of Sennheiser HD 280 stereo headphones. Participants were given the option of using a volume dial to adjust the volume of the narration (and embedded background music if applicable) to their individual comfort-level. The high-quality Sennheiser headphones are closed, circumaural headphones and were specifically selected to reduce noise associated with the projectors of the Reality Center and to eliminate aural distractions from other participants and researchers as much as possible.

3. Posttest Stage: After participants finished watching the VirSchool history lesson they were seated at a desk (see position 3 in Figure 34) in a different section of the laboratory separated by a curtain from the positions of Stage 1 and 2 to reduce visual distractions by other participants and researchers. Participants wore noise-cancelling earmuffs

to reduce aural distraction while answering a posttest questionnaire (see Appendix C, p. 223) containing multiple-choice questions about facts that were presented by the Avatar in the VirSchool history lesson. Participants were also asked about feelings of immersion (see Appendix C, p. 231) and their level of experience with computer games and music (see Appendix C, p. 235), as discussed in detail in the previous section.

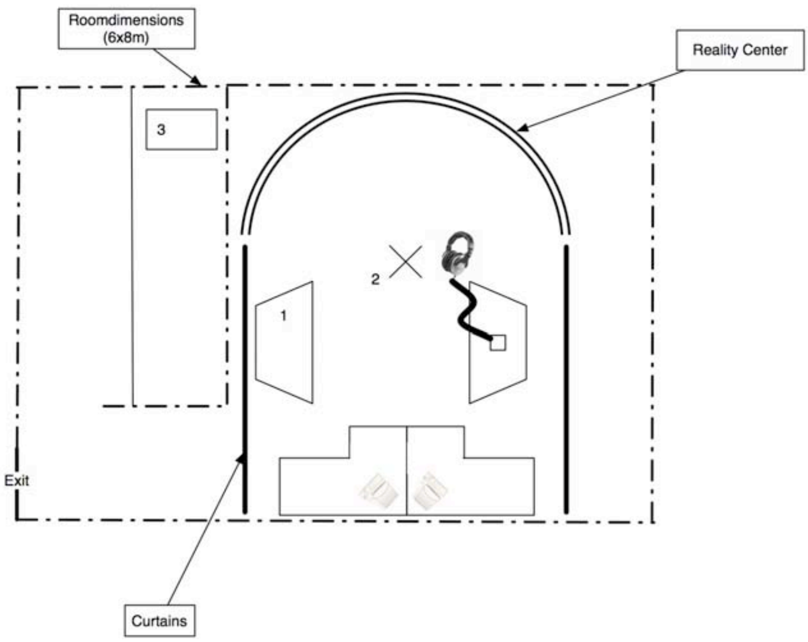
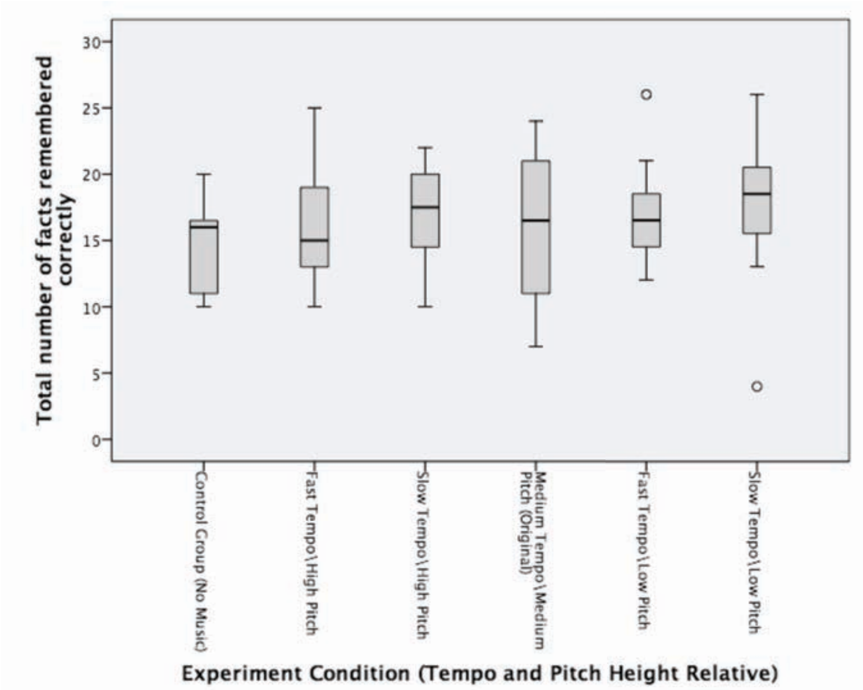


Figure 34: Experiment Setup of the Reality Center.

4.1.5 Results

Participants were asked 29 questions from the VirSchool history lesson about the Macquarie Lighthouse. The total number of facts remembered correctly under each of the experimental conditions is illustrated in Figure 35 and Figure 36. Figure 35 shows that the median of the total number of facts remembered correctly is the highest at slow tempo and lowered pitch. It can also be seen that


Total number of facts remembered correctly
30
25
20
15
10
5
0
Control Group (No Music)
Fast Tempo\High Pitch
Slow Tempo\High Pitch
Medium Tempo\Medium Pitch (Original)
Fast Tempo\Low Pitch
Slow Tempo\Low Pitch
Experiment Condition (Tempo and Pitch Height Relative)

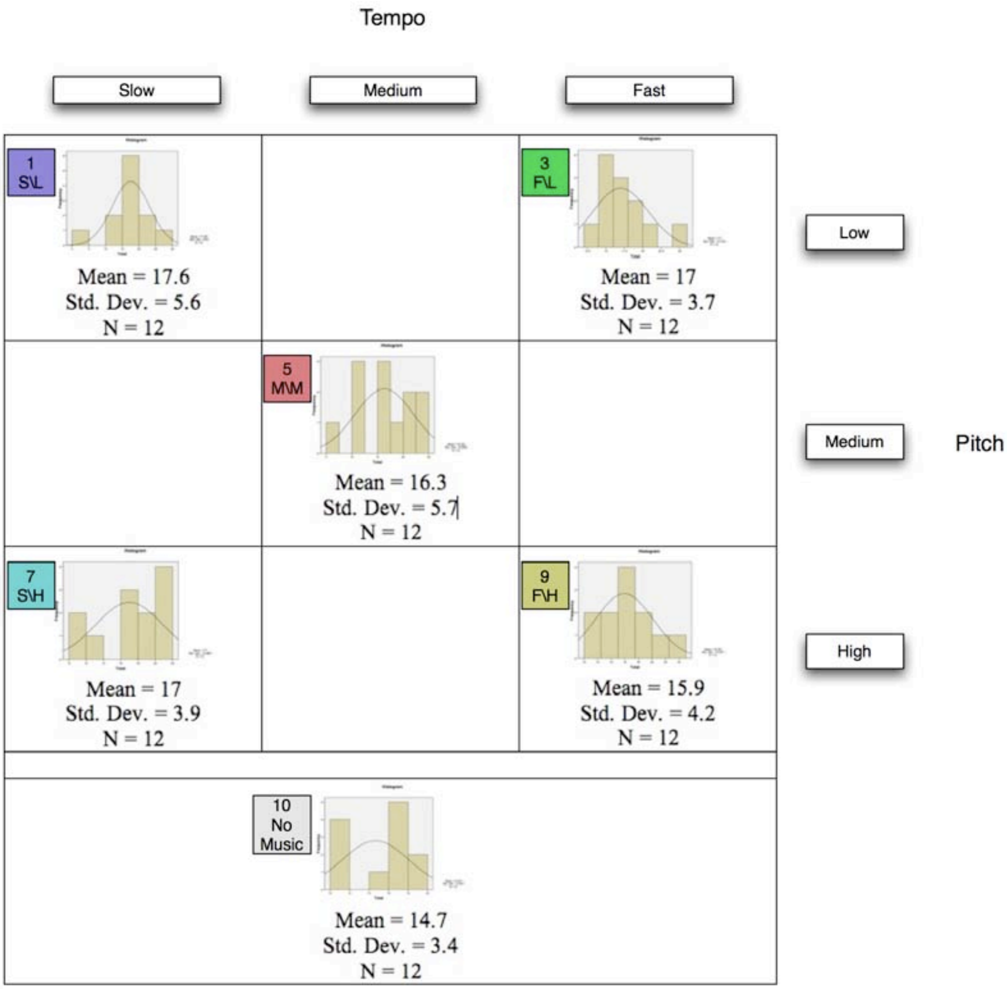


Figure 36: Comparison of the mean number of facts learned from the VirSchool history lesson.

Although these numbers and the graphs seem to indicate a relationship between experimental condition (tempo and pitch) and the number of facts remembered correctly, the magnitudes of the mean scores are in fact close to each other (i.e. the effect size is small) and variations are wide. Therefore, it was not possible to detect any statistically significant difference between the means with the current sample size. For example, if we disregard the 'No Music' control condition and compare the difference between musical experimental conditions 1 (slow tempo/low pitch), which has the highest number of learned facts (17.6 facts remembered correctly), and musical experimental condition 9 (fast tempo/high pitch), which has the lowest number of learned facts (15.9 facts remembered correctly), we see that this difference is less than two facts (1.7).

An alpha level of .05 was used for statistical tests and although participants who listened to background music during the VirSchool history lesson performed better than their peers in the 'No Music' control group, a one-way analysis of variance (ANOVA) revealed that the experimental (music) conditions were not a significant main effect for remembrance ($F_{(5,71)}=0.63$, $p=0.68$). In other words, we were unable to detect any statistically significant difference between the mean number of facts remembered correctly by participants under the six experimental conditions (one control group and five combinations of tempo and pitch).

Furthermore, we separately investigated the effects of tempo and pitch on number of facts remembered correctly. Figure 37 shows the effects of absolute tempo and pitch on the median number of facts remembered correctly with the medians for each category. For this analysis the original soundtrack condition (experiment condition 5 - medium tempo/medium pitch) and the 'No Music' condition (experiment condition 10) were removed. Instead, this analysis focused on the four tempo (Fast, Slow) and pitch conditions (Low, High) (experiment conditions 1, 3, 7 and 9 in Figure 36).

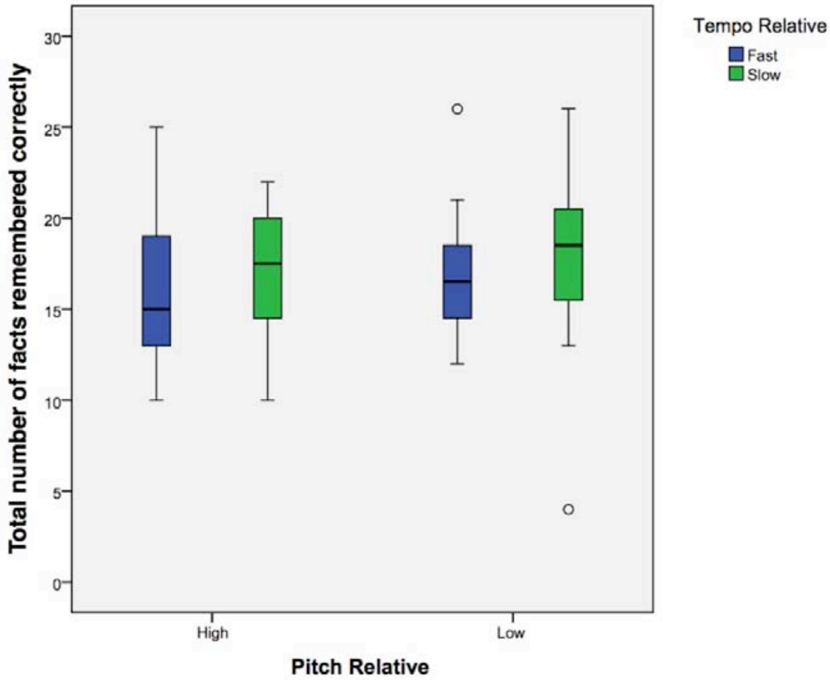


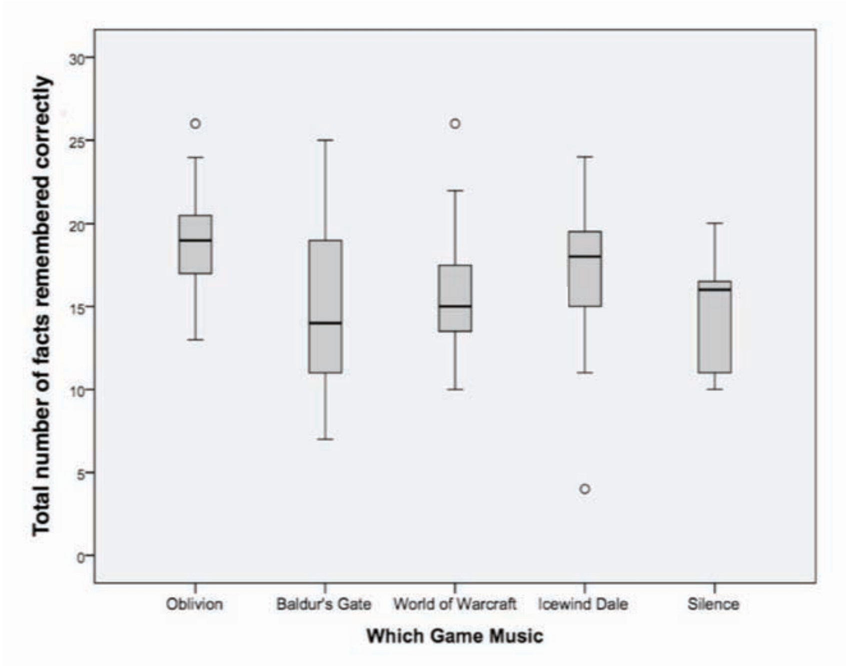
Figure 37: The total number of facts remembered correctly (y-axis) for 2x2 (tempo x pitch) matrix (original soundtrack condition (medium tempo/medium pitch) and 'No Music' condition removed)

Figure 37 shows that the median number of facts remembered correctly was higher under the low pitch condition than under the high pitch condition. Figure 37 also shows that the slow tempo had a better effect on remembrance of the facts from the VirSchool history lesson than the fast tempo (regardless of the pitch).

A series of Shapiro-Wilk tests for normality of the total number of facts remembered correctly by tempo, pitch and interaction showed that none of these are significantly different from the normal distribution ($p>0.05$). Levene's test was used to test that the error variance of the dependent variable (Total = Number of facts remembered correctly) was equal across groups. We found no evidence against the homogeneity of the variances ($p>0.05$).

Two-way Analysis of Variance (ANOVA) was used to investigate the effects of tempo and pitch on the average number of facts remembered correctly which showed no statistically significant effect of either (both $F_{(1,45)}=0.44$, $p=0.51$) and no significant interaction ($F_{(1,44)}=0.04$, $p=0.85$).

Figure 38 shows that the 'Oblivion' soundtrack had the highest median and small variation (compared to other conditions) while the 'Baldur's Gate' soundtrack had the lowest median and the widest variation of the total number of facts remembered correctly. The effects of game music (Oblivion, Baldur's Gate, World of Warcraft, Icewind Dale) were tested against the 'No Music' condition (disregarding tempo and pitch all together). Since we were not interested in the differences between the different music conditions but instead wanted to test whether any musical experimental condition was significantly different from the 'No Music' condition it was decided to use Dunnett's two-sided t-test, which compares a control group to different experimental conditions. In this analysis we found a statistically significant difference ($p=0.034$) between the 'Oblivion' soundtrack and the 'No Music' condition. Those participants who listened to the 'Oblivion' soundtrack, on average answered 4.4 more questions correctly (95% confidence intervals 0.3 – 8.5) than their peers in the 'No Music' control group.


Total number of facts remembered correctly
0
5
10
15
20
25
30
Oblivion
Baldur's Gate
World of Warcraft
Icewind Dale
Silence
Which Game Music

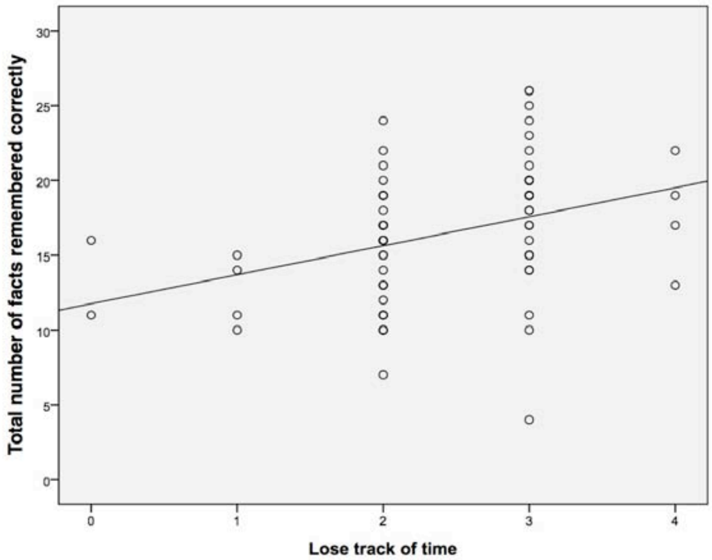


Figure 39: Linear regression of the correlation between losing track of time and the total number of facts remembered correctly.

Based on the linear regression, we conclude that on average if participants did not lose track of time, they answered 11.8 questions correctly. For each further level of losing track of time (i.e. from 1 to 4 on the scale) the total number of facts remembered correctly increased by 1.9. For example, if participants completely lost track of time then on average we expect that they would have answered 19.4 questions correctly, which is 7.6 questions more than those participants who did not lose track of time at all. We could not find a significant relationship between tempo or pitch of the soundtrack and losing track of time.

Neither the main effects of experimental condition ($F_{(5, 61)}$, p=0.474), and language ($F_{(1, 61)}$, p=0.129, variable A3 in Table 3), nor their interaction ($F_{(4, 61)}$, p=0.124) were statistically significant factors. The power of detecting any significant interaction was low (0.54) thus we could not be sure that language and experimental condition did not have a statistically significant effect on the number of facts remembered correctly.

Table 3: Relationship of tempo and pitch categories (experiment condition) and language (A3)

Dependent Variable:Total number of facts answered correctly

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	275.093[a]	10	27.509	1.474	.171
Intercept	9733.463	1	9733.463	521.555	.000
ExperimentCondition	85.874	5	17.175	.920	.474
A3	44.222	1	44.222	2.370	.129
ExperimentCondition * A3	140.801	4	35.200	1.886	.124
Error	1138.407	61	18.662		
Total	20818.000	72			
Corrected Total	1413.500	71			

Although, the ANOVA assumptions of normality and equal variances were satisfied for the test of experiment conditions and language, the number of observations ranged from 2 to 12 for the interaction. For example, only two participants who indicated English as their first language received the fast tempo/low pitch condition as compared to ten participants in the same condition who were non-native English speakers. Similarly, three native English speakers received the medium tempo/medium pitch condition versus nine non-native English speakers. Because of these small numbers in some of the cells results would not be statistically sound and it was therefore inferred that to draw a valid conclusion, a bigger sample size is required. This finding concludes the data analysis from Experiment 1 and we will discuss these results in the next section.

4.1.6 Discussion

The tempo and pitch manipulations showed no significant differences on the mean number of facts remembered correctly, thus, there is no evidence to reject the null hypothesis (that the mean number of facts remembered correctly would be similar whether there was background music or not). However, when we looked at each individual soundtrack and compared it to the 'No Music' condition (control group) we found a statistically significant difference between the 'Oblivion' soundtrack and the control group. One conjecture is that the Oblivion soundtrack could be the most congruent piece for the setting of the lighthouse scene. The importance of congruency between music and accompanying media has been the subject of considerable research. Lipscomb *et al.* (1994) for example found that participants in a study were able to accurately identify the original soundtrack that was written for a particular movie scene by the composer from amongst a total number of five soundtracks. Properties of music that are congruent with accompanying media act to highlight certain features of those media over others and hence can greatly influence how those media are remembered. According to the congruence-associationist model outlined by Marshall and Cohen (1988) and Cohen (2005), sources of congruency act by directing attention to particular aspects of an accompanying film over others (see also Bolivar *et al.*, 1994). These effects on attention, in turn, influence interpretations and memory for such material. Thus, participants might have unknowingly responded best to the music that was most congruent to the visual representation because it was composed for the video game (i.e. Oblivion) of which we used the construction set to create the VirSchool history lesson.

Apart from the beneficial influence of the Oblivion soundtrack, a statistically significant effect was found between participants' feeling of immersion into the virtual environment and the number of questions answered correctly. Those who said that they were more immersed (by saying that they lost track of time) in the VirSchool history lesson on average remembered more facts than those who said that they did not lose track of time.

The observed power for the first experiment was low (0.216) when we tested any difference between the six experimental conditions. This was possibly due to the small sample size in each experimental condition, which was not sufficient to detect a small effect (the difference between the mean number of facts remembers correctly), and the large standard deviations compared to the means (the lowest standard deviation – 3.4 – was 23% of the related mean -14.7 facts remembered correctly). Furthermore, language might have had an effect on the number of facts remembered correctly but not enough data was available to investigate this possible relationship.

4.2 Experiment 2

The results of Experiment 1 were used in the design of Experiment 2, since the low statistical power and the small number of participants in each of the experimental conditions in Experiment 1 made statistical analysis less reliable. This small number of participants was mostly the result of using a 'Between Subjects Design'. Where the 'Between Subjects Design' was chosen to avoid too many changes of stimuli which could distract participants, a 'Between Subjects Design' has the disadvantage that it compares the results of one group of participants who were exposed to Stimulus 1 with another group of participants who were exposed to Stimulus 2 (or 3, 4, *n*), thus using different participants for different stimuli. Therefore, a 'Between Subjects Design' does not allow an analysis of the performance of one participant in different conditions. The same participant might perform better/worse under the influence of a different stimulus but this cannot be investigated because once a participant has been exposed to one stimulus he or she could not be used for a different stimulus – The history of the Macquarie Lighthouse would have already been revealed under the influence of the first stimulus. Therefore, for Experiment 2, it was decided to use a 'Within Subjects Design'. It should be mentioned that when we use the term 'Within Subjects' design we refer to a 'Repeated Measures Design' with one within subjects factor of 'Music' and 'No Music'.

In a 'Within Subjects Design' each participant receives all conditions instead of only one as in a 'Between Subjects Design' (Experiment 1). A 'Within Subjects Design' is also considered to be more powerful (Maxwell *et al.*, 2004, p. 562) in regards to conclusions that are drawn from associated data analysis if responses of participants under different conditions are positively correlated. Generally speaking, the variance of difference scores tend to be less in a 'Within Subjects Design' than the variance of the observations on which they are based[72] (Cacioppo *et al.*, 2000, p. 880). Furthermore, in a 'Within Subjects Design', data for two (or more) treatments (stimuli) is gathered from the same participant rather than comparing the performance of one or more participants under different conditions with each other, as is the case in a 'Between Subjects Design' where each participant only receives treatment with one stimulus.

Moreover, a 'Within Subjects Design' reduces errors that are due to individual differences between participants by comparing the performance of the same participant(s) under the influence of all possible stimuli. In the present experiment this means that participants received two conditions - 'Background Music' (Music) and 'No Background Music' (No Music) in the same experiment

[72] As an example, the pre- and post-test scores (in other experiments, since the present experiment did not record a pre-test score) might be 10 and 15 for one participant and 50 and 55 for another participant. This means that there is a big difference between the original scores (50-10=40 points difference), but no difference between the difference scores (15-10=5 and 55-50=5 points difference).

session. Participants thus acted as their own control group. Because of the increased statistical power of the 'Within Subjects' experiment design, fewer participants were required to draw valid conclusions. Thus, it was possible to reduce the number of participants from 72 (Experiment 1) to 48 (Experiment 2).

The duration of the VirSchool history lesson was the same as in Experiment 1, 10:59 minutes (plus 43 seconds introduction (which was without stimuli) = 11:38 minutes). In order to increase the number of participants for each condition (Music, No Music), the VirSchool history lesson was split in two halves in a 'Crossover' experiment design with one stimulus being assigned to each half. Thus, all participants were exposed to the 'Music' and 'No Music' condition. Figure 40 shows the two versions that were created of the VirSchool history lesson. One version featured 'Music' in the first half and 'No Music' in the second half (see Stimuli Order Group 1 in Figure 40). In the second version participants were presented with 'No Music' in the first half and 'Music' in the second half (see Stimuli Order Group 2 in Figure 40). This in effect doubled the number of participants in each condition because now, instead of giving 24 participants the 'Music' stimulus and 24 participants the 'No Music' stimulus, with this design 48 participants were exposed to the 'Music' stimulus and the same 48 participants were also exposed to the 'No Music' stimulus. The reason for reversing the order of the stimuli was to ensure that any observations of significant differences between music and no music were due to the stimuli and not due to varying difficulty levels between the two halves of the VirSchool history lesson (i.e. that information in one half was easier to remember than information from the other half). In the remainder of this document we will refer to these two versions of the VirSchool history lesson as 'Stimuli Order Group 1' and 'Stimuli Order Group 2'.

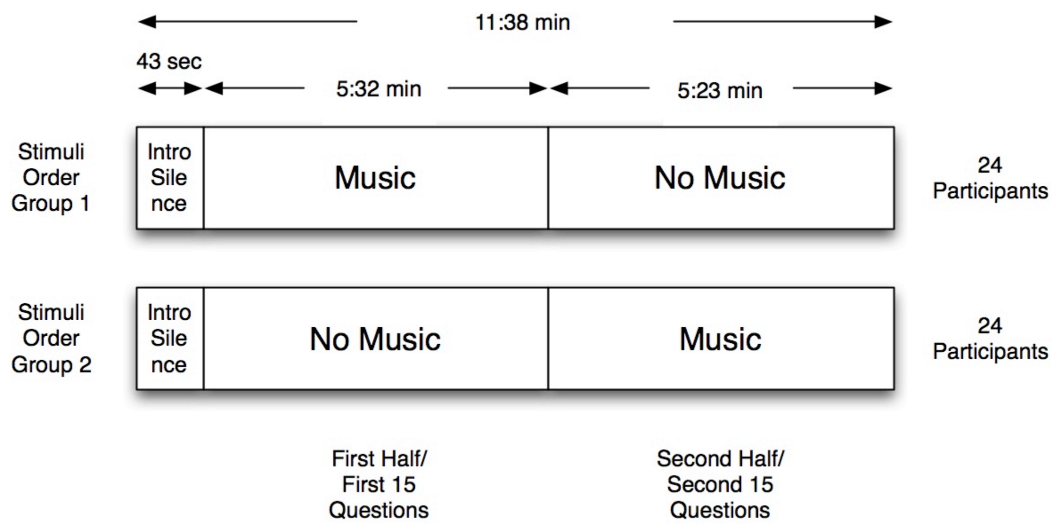


Figure 40: The experiment design for Experiment 2 included two versions of the VirSchool history lesson.

As can be seen in Figure 40, the first half of the VirSchool history lesson played for 5:32 minutes while the second half played for 5:23 minutes. The slight difference in length is due to a sectional break that could only be made after a sentence was finished by the narrator-Avatar. Because of this changed experiment design, the part of the questionnaire that included the questions about the historical facts of the Macquarie Lighthouse had to be adapted as will be explained in Section 4.2.3.

Experiment 2 was originally designed with a power of 0.80 and α=0.05 for two experimental conditions which gave us 48 participants for each stimulus (Music, No Music) and 24 participants for each stimulus order group (expected effect size = 2.45 and standard deviation = 3). It was planned to undertake the experiment by using the Reality Center only, however, exactly half way through the experiment (after 24 participants) a light bulb blew up in one of the projectors of the Reality Center that could not be replaced in a timely manner. Due to this technical problem it was decided to continue the experiment with the 3-monitor display system that had previously been used during the development phase of the VirSchool history lesson. Thus, the physical experiment setup for Experiment 2 consisted not only of the Reality Center but also used the 3-monitor display system for the second group of 24 participants who received the stimuli (Music, No Music). This event and the consequential adjustment of the experiment equipment effectively changed the experiment design from a 'Repeated Measures' design with one within subjects factor (Music, No Music) and *one* between subjects factor (Stimuli Order – 'Music First', 'No Music First') to a 'Repeated Measures' design with one within subjects factor (Music, No Music) and *two* between subjects factors (Stimuli Order – 'Music First', 'No Music First' & Reality Center, 3-monitor display system) instead of one (Stimuli Order – 'Music First', 'No Music First'). Unfortunately, the observed power of the comparisons of the mean number of correctly answered questions in each half of the experiment (0.65) was lower than the planned power (0.80) for Experiment 2 (see section 4.2.5 for observed power) which might be due to the introduction of another between subjects factor (display system) or due to the smaller than expected difference between the two halves. Despite the disadvantage of affecting our experiment design, the failure of the light bulb opened the opportunity to examine how different display systems affected participants' memory. In fact, the equipment failure revealed interesting results, as we will see later.

For the experimental stimuli, one musical stimulus was created as an amalgamation of the beneficial factors of Experiment 1. Similar to Experiment 1, the analysis and interpretation of the results of Experiment 2 are detailed in the following sections.

4.2.1 Stimuli

Since Experiment 2 built upon results and experiences from Experiment 1, not only the questionnaire (see section 4.2.3) but also the stimuli had to be adapted to satisfy the new requirements and take into account the findings from Experiment 1. In section 4.1.1 the varying relative and absolute tempi of the musical stimuli were mentioned and one problem that had become obvious during analysis of the data from Experiment 1 was that the relative and absolute tempo of the various soundtracks differed quite widely from each other (see Table 2 on page 122). What is medium (M) *relative* tempo for one soundtrack can be fast (F) *absolute* tempo for another soundtrack. For example, the medium tempo of World of Warcraft (WoW) is 142 beats per minute (BPM) which is quite different from the slowest soundtrack in the same (medium) category – Icewind Dale (IWD) with 95 BPM. Also, the medium tempo of WoW (142 BPM) is just as fast as the tempo of the Oblivion soundtrack in the fast condition (146 BPM).

The same problem occurred in regards to pitch. For example, the Oblivion soundtrack could be composed in the key of 'C' and the soundtrack for Baldur's Gate could be composed in the key of 'D#'. Although it was not investigated which particular key the different soundtracks were composed in, the inherent problem is obvious - Raising or lowering the pitch (relatively) by 2 semitones changes the absolute pitch and what is medium relative pitch for one soundtrack can be low absolute pitch for another and vice versa.

Although we did not find any significant difference between the different tempo and pitch conditions in Experiment 1, it was decided to eliminate the possible problems of differing absolute tempo and pitch of multiple soundtracks, by using only one musical track from the soundtrack of one computer RPG and manipulating its tempo and pitch, therefore, controlling variability of tempo and pitch for Experiment 2. Despite the fact that the results from the investigations of the tempo and pitch manipulations from Experiment 1 did not show a statistically significant result, it was decided to focus on those conditions which showed the most beneficial tendencies – slowed down tempo (-21% as in Experiment 1) and lowered pitch (-2 Semitones as in Experiment 1) to increase the possibility of finding a difference between the 'Music' and 'No Music' conditions. Because in Experiment 1 the track 'town_03.mp3' from the 'Oblivion' soundtrack showed a positive effect on memory at a statistically significant level (compared to the 'No Music' condition) on the mean number of facts remembered correctly from the VirSchool history lesson, it was decided to use this track for the tempo and pitch manipulations. It is acknowledged that this approach means that the inferences that are extracted from the results of the subsequent experiments are not generalisable for the whole genre of soundtracks of computer RPG's. Instead, results are conclusive for one particular tempo (92 BPM absolute tempo) and pitch (-2 semitones absolute pitch) of one track (town_3.mp3, to be found in the install directory of the game) of the soundtrack of one RPG (Oblivion).

The above explanations outline a number of changes to the experimental conditions for Experiment 2 as compared to Experiment 1. In order to give a comprehensive overview of these changes, the following list summarises the key points. For the adapted experiment design, it was decided to

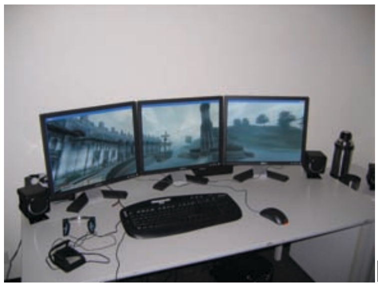
- Use one musical track (town_03.mp3) of one soundtrack (Oblivion) that showed a positive statistically significant effect on the number of facts remembered correctly by participants in Experiment 1.
- Manipulate tempo and pitch of this track to the most beneficial combination of lowered tempo and reduced pitch (as outlined in Experiment 1).

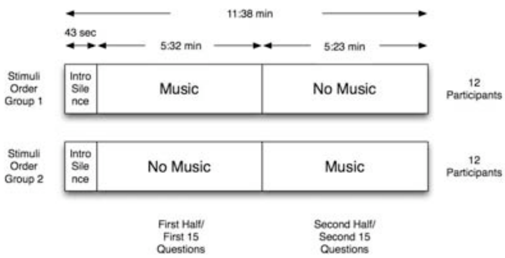
- Use a 'Repeated Measures' design with one within subjects factor (Music, No Music) and one between subjects factor (Stimuli Order – 'Music First', 'No Music First').
- Split the VirSchool history lesson into two halves and expose all participants to both stimuli.
- Reverse the order in which the 'Music' and 'No Music' conditions were integrated for half the participants to avoid that an effect was observed due to the fact that facts in one half were easier to remember than in the other.
- Change the number of questions so that there were 15 questions from each half of the VirSchool history lesson (see Section 4.2.3 for a detailed explanation).
- Use the 3-monitor display system for the second half of the experiment because of equipment failure and consequently change the experiment design to a 'Repeated Measures' design with one within subjects factor (Music, No Music) and two between subjects factors (Stimuli Order – 'Music First', 'No Music First' & Reality Center, 3-monitor display system) instead of one between subjects factor (Stimuli Order – 'Music First', 'No Music First') as before the introduction of the 3-monitor display system.

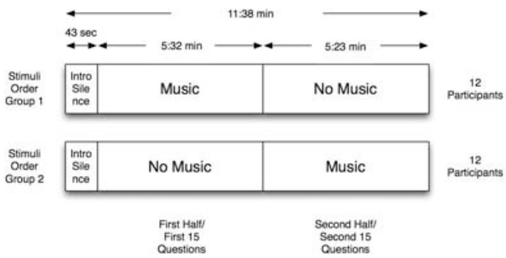
4.2.2 Participants

The participants were 48 undergraduate students (28 female, 20 male) aged between 18 to 43 years (mean 22.7 years of age, std=4.67). Students were recruited by advertisement on campus at Macquarie University, Sydney. Participants received 10 Australian Dollars for their involvement. Eighteen participants indicated English as their first language while 30 participants answered that English was their 'second or other' language (information in regards to the influence of language in this experiment is available in section

4.2.6). Because of the equipment failure and the consequential addition of the second display system (3-monitor display system) to the experiment design, half of the initially planned 48 participants had to be allocated to this new display system. Thus, the first group of 24 participants were assigned to 'Display System Group 1' - the Reality Center - and after exactly 24 participants the light bulb failed and the second group of 24 participants were assigned to 'Display System Group 2' - the 3-monitor display system (see Table 4). Consequently, 12 participants saw the VirSchool history lesson in Stimuli Order Group 1 ('Music' in the first half and 'No Music' in the second half) in the Reality Center, 12 participants saw the VirSchool history lesson in Stimuli Order Group 2 ('No Music' in the first half and 'Music' in the second half) in the Reality Center, 12 participants saw the VirSchool history lesson in Stimuli Order Group 1 ('Music' in the first half and 'No Music' in the second half) in the 3-monitor display system and 12 participants saw the VirSchool history lesson in Stimuli Order Group 2 ('No Music' in the first half and 'Music' in the second half) in the 3-monitor display system.




11:38 min
43 sec
5:32 min
5:23 min
Stimuli Order Group 1
Intro Sile nce
Music
No Music
12 Participants
Stimuli Order Group 2
Intro Sile nce
No Music
Music
12 Participants
First Half/ First 15 Questions
Second Half/ Second 15 Questions


11:38 min
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Stimuli Order Group 1
Intro Sile nce
Music
No Music
12 Participants
Stimuli Order Group 2
Intro Sile nce
No Music
Music
12 Participants
First Half/ First 15 Questions
Second Half/ Second 15 Questions

results in a width-of-display to distance-of-viewer-from-screen ratio of 1.95, which is about 22% bigger than the ratio for the 3-monitor display system. Despite the fact that possible artefacts would display slightly larger on the Reality Center this difference has been accepted by the researcher to be negligible. Thus, the possible slight difference in graphical display has not been investigated in the experiments.

4.2.3 Measures

As in Experiment 1, participants completed a questionnaire that gathered data in 4 different categories – biographical data, facts from the VirSchool history lesson, participants' feeling of immersion into the virtual environment and participants' previous experiences with computer games and music.

As mentioned before, the questionnaire from Experiment 1 had to be adapted to reflect the changes in experiment design. A problem from Experiment 1 was that the number of facts in the two halves (see Figure 40) of the VirSchool history lesson was unbalanced. This mismatch occurred because in Experiment 1 participants were exposed to only one condition (e.g. slow tempo music at increased pitch, medium tempo music at medium pitch, 'No Music', etc.) for the whole 10:59 minutes and in Experiment 1 it was not intended to compare the mean number of facts remembered correctly from the first half of the VirSchool history lesson with the second half. Thus, in Experiment 1, 19 questions were asked from the first half and 10 questions were asked from the second half of the VirSchool history lesson. For Experiment 2, however, it was crucial to compare the two halves of the VirSchool history lesson to allow a comparison of the mean number of facts remembered correctly from the two halves. Therefore, four questions were omitted from the first half of the VirSchool history lesson and five questions were added that were relevant to the facts presented in the second half.

This adaptation ensured that the questionnaire contained 15 questions for each half of the VirSchool history lesson (15 questions from the first half, 15 questions from the second half = 30 questions overall). The complexity and type of questions in both halves were similar (First Half – Three questions about years/dates, four questions about names (places, persons), three questions about numbers and five questions about other uncategorised information; Second Half - Two questions about years/dates, five questions about names (places, persons), six questions about numbers and two questions about other uncategorised information).

The following list shows the question categories and gives a representative overview of the questions that were asked in the questionnaire. The complete questionnaire is available in Appendix C as indicated in the respective sections.

Participants answered

- 4 questions about their biographical data (e.g. Age, Gender, First Language). For the complete set of questions refer to Appendix C, p. 237.

- 30 questions about the history of the Macquarie Lighthouse as covered in the VirSchool history lesson (e.g. "What was the name of the first lighthouse keeper?", "In which year was the first lighthouse built?", "How many people were stationed at the lighthouse?"). For the complete set of questions refer to Appendix C, p. 238.

- 23 questions about participants' preferences in regards to different parts of the video narration (e.g. "Do you think that this virtual environment was a useful learning tool?", "Did you like the music you were listening to?") as well as some questions about the immersiveness of the video narration (e.g. "How well were you concentrating?", "How much did you lose track of time?"). For the complete set of questions refer to Appendix C, p. 245.

- 5 questions about participants' prior experience with music and computer/console games (e.g. "How many years have you been playing computer/console games?", "How many years have you been playing a musical instrument?"). For the complete set of questions refer to Appendix C, p. 250.

4.2.4 Procedure

Experiment 2 consisted of the same three stages - pretest, experiment and posttest - as Experiment 1, except that only half of the participants watched the VirSchool history lesson in the Reality Center (see Figure 41). The other half of the participants watched the VirSchool history lesson on the 3-monitor display system (see Figure 42).

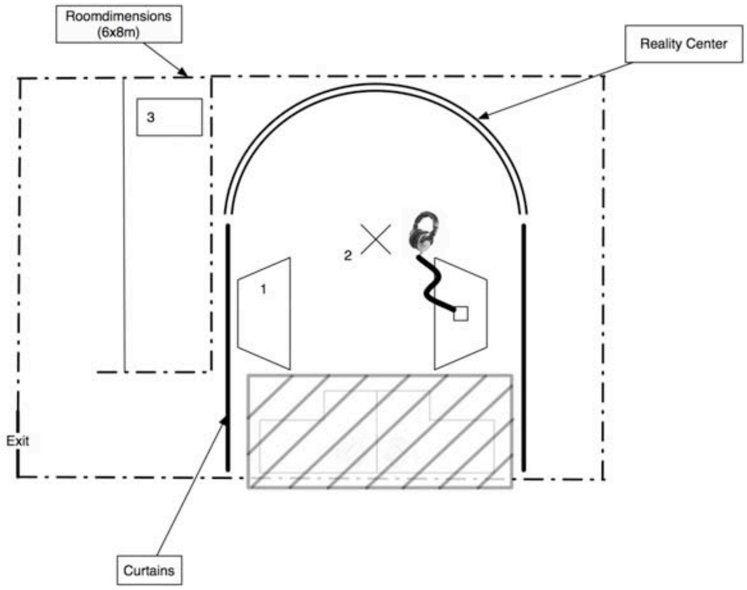


Figure 41: Experiment Setup of the Reality Center. Participants answered a pretest questionnaire at 1, then watched the VirSchool history lesson at 2 and answered a posttest questionnaire at 3. The Reality Center (position 2) was used for one half of the participants while the 3-monitor display system (concealed by crossed-out area, instead see Figure 42) was used for the other half of the participants.

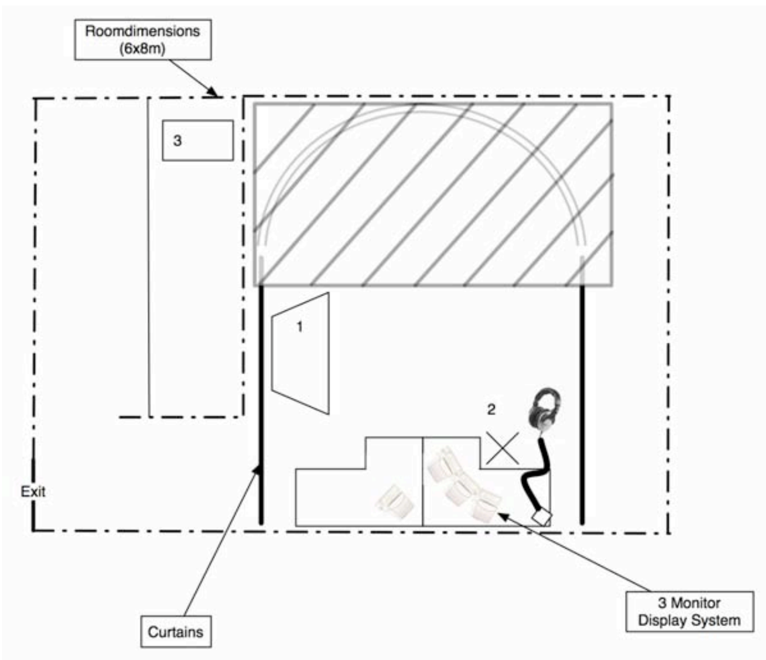


Figure 42: Experiment Setup of the 3-monitor display system. Participants answered a pretest questionnaire at 1, then watched the VirSchool history lesson at 2 and answered a posttest questionnaire at 3. This 3-monitor display system (position 2) was used for one half of the participants while the Reality Center (concealed by crossed-out area, instead see Figure 41) was used for the other half of the participants.

1. Pretest Stage: Like in Experiment 1, participants in Experiment 2 started the experiment by answering a short pretest questionnaire (see Appendix C, p. 237) about biographical data (see position 1 in Figure 41 and Figure 42).

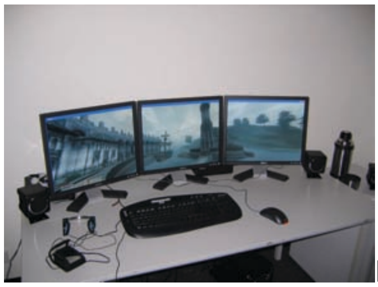
2. Experiment Stage: One participant watched the VirSchool history lesson about the Macquarie Lighthouse (10:59 minutes) at a time. Participants were asked to sit in the centre of the Reality Center (see position 2 in Figure 41) ***or*** the 3-monitor display system (see position 2 in Figure 42) depending on the group they were assigned to. Participants watched and listened to the stimuli described in detail in Section 4.2.1. Participants listened to the Avatar and the background music through the same Sennheiser HD 280 stereo headphones that were used in Experiment 1. Participants were also given the option of using a volume dial to adjust the volume of the narration (and embedded background music) to their individual comfort-level. It is important to note that in Experiment 2 all participants listened to one half of the VirSchool history lesson with background music **and** one half of the VirSchool history lesson without background music.

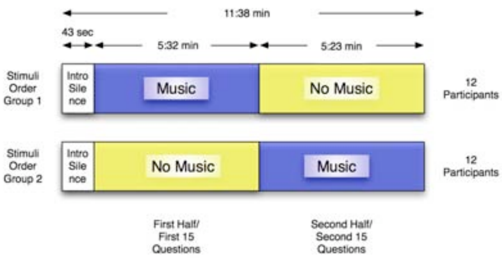
3. Posttest Stage: After participants finished watching the VirSchool history lesson they were seated at a desk (see position 3 in Figure 41 and Figure 42) in a different section of the laboratory separated by a curtain from the positions of Stage 1 and 2 to reduce visual distractions by researchers and other participants. Participants wore noise-cancelling earmuffs to reduce aural distractions while answering an adapted posttest questionnaire containing multiple-choice questions (see Appendix C, p. 238) about facts that were presented by the Avatar in the VirSchool history lesson. The original questionnaire from Experiment 1 was adapted to satisfy the requirements of Experiment 2. Adaptations were necessary in terms of

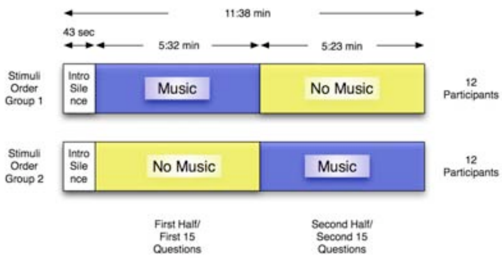
the number of questions that were asked from the first and the second half of the VirSchool history lesson as explained in Section 4.2.3. Participants were also asked about feelings of immersion (see Appendix C, p. 245) and their level of experience with computer games and music (see Appendix C, p. 250).

4.2.5 Results

From the results of Experiment 1 it was anticipated that Experiment 2 would provide more evidence for the initial result that the Oblivion 'Music' condition at slower tempo and reduced pitch would improve memory of facts that were taught in the VirSchool history lesson. However, the results of Experiment 2 did not show such an improvement as a paired t-test revealed. For this analysis, the mean difference between the number of facts remembered correctly from the 'Music' (4 subgroups, coloured blue in Table 5) and 'No Music' (4 subgroups, coloured yellow in Table 5) conditions of the two 'Stimuli Order' groups (see Stimuli Order Group 1 and Stimuli Order Group 2 in Table 5) were compared by aggregating the results across the two 'display systems' groups.




11:38 min
43 sec
5:32 min
5:23 min
Stimuli Order Group 1
Intro Silence
Music
No Music
12 Participants
Stimuli Order Group 2
Intro Silence
No Music
Music
12 Participants
First Half/ First 15 Questions
Second Half/ Second 15 Questions


11:38 min
43 sec
5:32 min
5:23 min
Stimuli Order Group 1
Intro Silence
Music
No Music
12 Participants
Stimuli Order Group 2
Intro Silence
No Music
Music
12 Participants
First Half/ First 15 Questions
Second Half/ Second 15 Questions

the results from Experiment 2 contradict those results. Thus, further analyses of the data were conducted.

Following the non-significant difference between the 'Music' and 'No Music' conditions, we investigated whether the mean number of facts remembered correctly differed between the two display systems ignoring the order of the stimuli (i.e. combining the 'Music' and 'No Music' conditions in both display systems, see Figure 43). We found a statistically significant difference (t_{46}= -2.209, p=0.032) between the two display systems where on average in the 3-monitor display system (mean=17.96, std=4.60) participants remembered 3.0 facts more about the history of the Macquarie Lighthouse than participants using the Reality Center (mean=14.96, std=4.81).

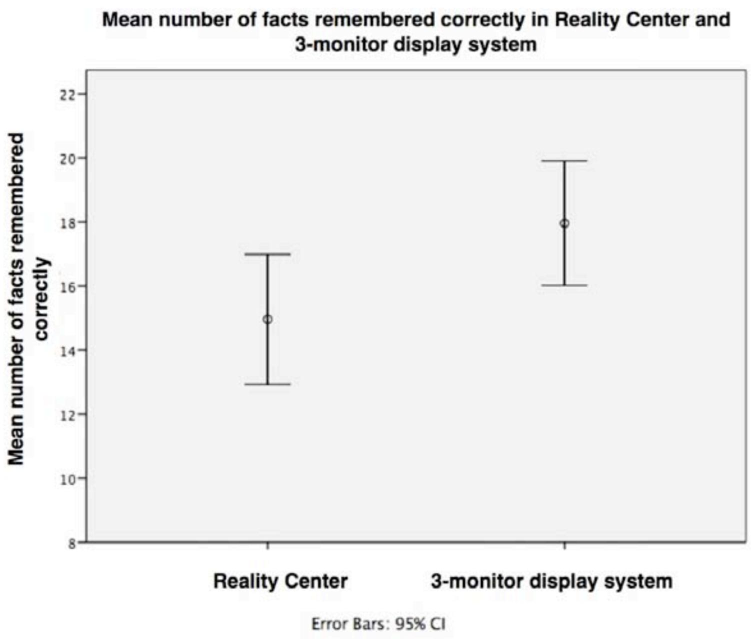


Figure 43: Mean number of facts remembered correctly in Reality Center and 3-monitor display system ('Music' and 'No Music' combined). Participants remembered significantly more facts in the 3-monitor display system. Whiskers show 95% confidence intervals.

Furthermore, a repeated measures one way ANOVA was performed since this experiment was designed as a 'Within Subjects' experiment. Adjustments for multiple testing are done when comparing subsets of the data set (i.e. pairwise comparisons of the between subjects factors). The Bonferonni adjustments used in these analyses (explained in detail on page 162) ensured that the Type I error rate remained at 5% level. The hypothesis we assumed was that the mean number of facts remembered correctly in the two parts of the experiment (first half, second half) were not significantly different from each other *between display systems* (i.e. experiment halves = within subjects factor and display systems = between subjects factor).

This repeated measures one-way ANOVA revealed that the mean number of facts remembered correctly for each part of the experiment was significantly different from each other. Regardless of the experimental conditions ('Music', 'No Music') on average participants remembered more facts correctly in the second half of the experiment ($F_{(1,46)}=4.78$, $p=0.034$), though this was a relatively small effect size (eta-squared = .09). Mauchly's test showed a violation of sphericity, which was compensated by an epsilon adjustment. After the epsilon adjustment by three different methods (Greenhouse-Geisser, Huynh-Feldt, and lower bound) we found the observed power of this test to be 0.57. The between subjects effect (Reality Center or 3-monitor display system) was a significant factor ($F_{(1,46)}=4.88$, $p=0.032$) and the power of this test was 0.58. Although, this analysis supported our earlier findings (independent t-test), since the power is less than 0.80, we do not have adequate power to assume no Type II error was made in this analysis.

Furthermore, we investigated possible interactions between stimuli and display systems. Again the data was analysed while disregarding the stimuli order. As can be seen in Figure 44, the medians of the total number of questions answered correctly were equal for the 'Music' and 'No Music' conditions (7) in the Reality

Center while the median for the 'No Music' (9.5) condition was greater than the median for the 'Music' (8) condition in the 3-monitor display system.

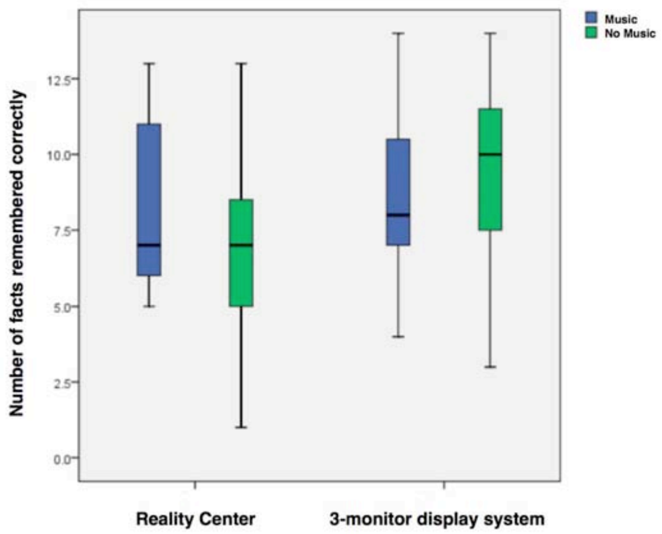


Figure 44: The total number of facts remembered correctly under different experimental conditions (Reality Center, 3-monitor display system & 'Music', 'No Music').

Both stimuli (Music, No Music) were investigated separately to determine any significant difference between them.

Firstly, the means of the 'No Music' conditions of both display systems (coloured green in Figure 44) were compared with each other (ignoring the 'Music' conditions). Although the distribution of the total number of facts remembered correctly looks wide (see Figure 44), both categories, 'No Music Only' in the Reality Center (p=0.780) and 'No Music Only' in the 3-monitor display system (p=0.348) were not significantly different from the normal distribution (Shapiro-Wilk normality tests). An independent t-test for the mean number of facts remembered correctly for 'No Music' in the Reality Center (mean=6.79, std=2.65) and 'No Music' in the 3-monitor display system (mean=9.38, std=2.73) showed that there was a highly statistically significant difference between the mean number of questions answered correctly (t_{46}= -3.32, p=0.002) for the 'No Music' condition in each display system (see Figure 45). Participants who watched the VirSchool history lesson in the 'No Music' condition in the 3-monitor display system on average remembered 2.59 facts more than participants in the Reality Center. Note that these results refer to only one half of the VirSchool history lesson ('No Music' only, 'Music' condition ignored) which means that participants in the 'No Music' condition of the 3-monitor display system remembered 2.59 facts more out of 15 questions. This means that the participants who were using the 3-monitor display system remembered 17.3% more facts correctly than their peers in the 'No Music' condition in the Reality Center (total remembrance of facts from 'No Music' condition in Reality Center=45.2%, total remembrance of facts from 'No Music' condition in 3-monitor display system 62.5%).

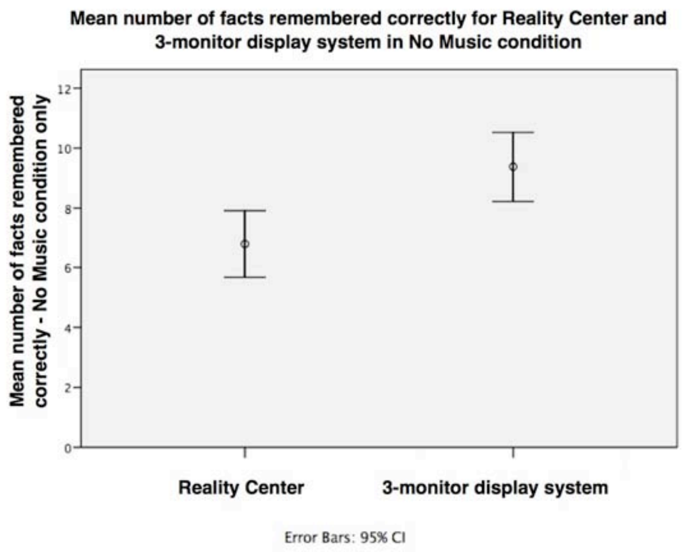
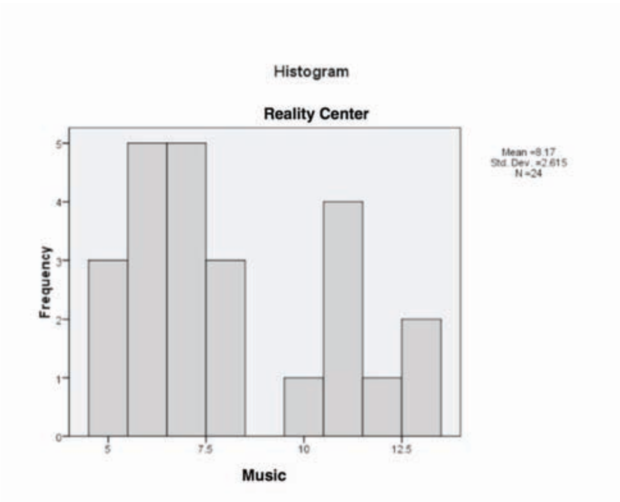


Figure 45: The mean number of facts remembered correctly in the 'No Music' condition was statistically significantly different between the two display systems. Participants performed better in the 3-monitor display system as compared to the Reality Center.

Secondly, we compared the means of the 'Music' conditions of both display systems (coloured blue in Figure 44) with each other (ignoring the 'No Music' conditions). Although, the Shapiro-Wilk normality test provided evidence against the normality of the total number of facts remembered correctly for one category


Histogram
Reality Center
Mean =8.17
Std. Dev. =2.615
N =24
Frequency
0
1
2
3
4
5
5
7.5
10
12.5
Music

one-way ANOVA revealed that the mean number of facts remembered correctly for each part of the experiment were significantly different from each other. Regardless of the experimental conditions (Reality Center or 3-monitor display system) on average participants remembered more facts correctly in the second half of the experiment ($F_{(1,46)}$=4.84, p=0.033), although this was a relatively small effect size (eta-squared = .09). Mauchly's test showed a violation of sphericity, which was compensated by an epsilon adjustment. After the epsilon adjustment by three different methods (Greenhouse-Geisser, Huynh-Feldt, and lower bound) we found that the observed power of this test is 0.58. The between subjects factor ('Music first' or 'No Music' first) showed no significant effect on the number of facts remembered correctly *in the two halves* ($F_{(1,46)}$=0.003, p=0.954), however, due to very low power (0.05) for this test, there is a high probability of making a Type II error in this conclusion.

Table 6 summarises our findings from the statistical tests with descriptive statistics for each condition that was analysed.

Table 6: Descriptive Statistics for the total number of questions answered correctly under different experimental conditions

Experiment Condition	Mean	Std	Effect Size[^]	Statistic	P value
No Music	8.08	2.97	0.11	t_{47}=0.779	P=0.44[+]
Music[1]	8.38	2.56			
Reality Center	14.96	4.81	0.64	t_{46}=-2.209	P=0.032[*]
3-monitor display system[2]	17.96	4.60			
Music First	16.50	4.57	0.02	t_{46}=0.056	P=0.954[+]
No Music First[3]	16.42	5.30			
First Half	7.83	2.74	0.29	t_{46}=2.186	P=0.034[*]
Second Half[4]	8.62	2.75			
3- monitor display system - No Music	9.38	2.73	0.96	t_{46}=-3.32	P=0.002[#]
Reality Center – No Music[5]	6.79	2.65			
3- monitor display system – Music	8.58	2.54	0.16	t_{46}=-0.56	P=0.578[+]
Reality Center –Music[6]	8.17	2.62			
First half – Reality Center	7.13	2.58	0.001[^^]	$F_{(1,44)}$=0.064	P=0.801[+]
First half – 3- monitor display system	8.54	2.77			
Second half – Reality Center	7.83	2.82			
Second half -3- monitor display system[6]	9.42	2.48			
First half – Music First	8.00	2.28	0.018[^^]	$F_{(1,44)}$=0.784	P=0.381[+]
First half – No Music First	7.67	3.17			
Second half – Music First	8.50	2.75			
Second half –No Music First[6]	8.75	2.80			

[1] Paired t-test for the stimuli with display systems ignored

[2] Independent t-test for the display systems with stimuli ignored

[3] Independent t-test for the order of the stimuli with display systems ignored

[4] Paired t-test for the halves of the experiment with display systems ignored

[5] Independent t-test

[6] Repeated measures one-way ANOVA

[+] Not significant

[*] Significant at p=0.05

Significant at p=0.01

[^] Calculated by dividing the difference between the two means by the pooled standard deviation (Cohen's *d)*

^^ Partial eta squared

The mean number of facts remembered correctly did not significantly differ with the order of the stimuli ('Music First' or 'No Music First') during the VirSchool history lesson *across both 'Display System' groups* ($p>0.05$), however, we observed a statistically significant difference between the mean number of facts remembered correctly with the order of music presentation when data analysis was performed separately for each display system. The analysis used to explore the effects of the different factors on the mean number of facts remembered correctly was a repeated measures one way analysis of variance, with stimuli order and display systems as between subjects factors and the total number of facts remembered correctly in each half (questions 1–15 versus questions 16-30) as the within subjects factors.

In the following sections, a number of pairwise comparisons will be made, and tests of significance of the differences will be reported. These pairwise comparisons are a subset of the repeated measures one-way ANOVA presented in the present section. In order to maintain the Type I error rate at the nominal rate of 0.05, an adjusted p-value was used to judge whether the results of these comparisons were significant. Using the Bonferroni inequality (see Appendix E for a detailed explanation of the Bonferroni adjustment), the critical p-value was based on the number of comparisons that was made for each factor. As there were three factors, and each had two levels, the pairwise comparisons for each factor were made for each combination of the other two factors, meaning that there were four comparisons. As the Bonferroni adjustment takes account of the multiple comparisons by dividing nominal alpha by the number of comparisons, a critical value of $p= 0.05/4 = 0.0125$ was used in the discussions that follow. First we describe the findings from the Reality Center and afterwards we explain the results from the 3-monitor display system.

When we focus on the 'Stimuli Order Groups' in Table 7 we see that the mean number of facts remembered correctly for 'Stimuli Order Group 1' in the Reality Center (ID 1&2 in Table 7) were similar between the two halves and the difference between the means was not significant ($t_{(44)}$=1.01, p>0.05). However, 'Stimuli Order Group 2' in the Reality Center (ID 5&6 in Table 7) showed a difference between the mean number of facts remembered correctly from the *first* and *second half.* The mean number of facts remembered correctly in the *first half* is 7.08 (std=3.12) compared to 9.17 (std=2.82) facts remembered correctly on average in the *second half*. This means that participants remembered a mean of 2.09 more facts that were presented in the second half of the VirSchool history lesson when they were not exposed to music in the first half and listened to background music in the second half. The difference was significant ($t_{(44)}$=3.16, p=0.003), which is less than the adjusted p-value of 0.0125.

Table 7: Pairwise comparison t-tests of Stimuli Order, Display Systems by Stimuli

ID	Experiment Condition	Mean	Std.	Mean Diffe-rence	Statistic	P value
1	Music First – Reality Center – First Half	7.17	2.04	0.67	$t_{(44)}$ = 1.01	$p=0.317^{+}$
2	Music First – Reality Center – Second Half	6.50	2.20			
3	Music First – 3 Monitor – First Half	8.83	2.29	1.67	$t_{(44)}$=2.53	$p=0.015^{*}$
4	Music First – 3 Monitor – Second Half	10.50	1.51			
5	No Music First – Reality Center – First Half	7.08	3.12	2.09	$t_{(44)}$=3.16	$p=0.003^{\#}$
6	No Music First – Reality Center – Second Half	9.17	2.82			
7	No Music First – 3 Monitor – First Half	8.25	3.25	0.08	$t_{(44)}$=0.13	$p=0.900^{+}$
8	No Music First – 3 Monitor – Second Half	8.33	2.84			

+ Not significant

* Significant at p=0.05

Significant at p=0.01

Similar to the comparison between the mean number of facts remembered correctly from the first and second half in the Reality Center, we compared the mean number of facts participants remembered correctly in each half of the VirSchool history lesson in the 3-monitor display system. As can be seen in Table 7, the results for 'Stimuli Order Group 2' in the 3-monitor display system (ID 7&8 in Table 7) were insignificant ($t_{(44)}$=0.13, p>0.05). Although, the mean number of facts remembered correctly in the *first half* of 'Stimuli Order Group 1' in the 3-monitor display system (ID 3 in Table 7) is 1.67 facts lower (mean= 8.83, std=2.29) than the mean number of facts remembered correctly by 'Stimuli Order Group 1' (see ID 4 in Table 7) in the *second half* (mean=10.5, std=1.51) in the 3-monitor display system, the mean difference of the number of facts remembered correctly for these groups was not statistically significant ($t_{(44)}$=2.53, p=0.015, >0.0125).

A repeated measures one-way ANOVA revealed that the mean number of facts remembered correctly for each part of the experiment were significantly different from each other (participants answered more questions correctly in the second half of the experiment, $F_{(1,44)}$=5.78, p=0.021), although this was a relatively small effect size (eta-squared = 0.12). Mauchly's test showed a violation of sphericity, which was compensated by an epsilon adjustment. After the epsilon adjustment by three different methods (Greenhouse-Geisser, Huynh-Feldt, and lower bound) we found that the observed power of this test is 0.65.

The interaction between the part of the experiment (experiment halves, questions 1–15 versus questions 16-30) and the order of the stimuli was not significant ($F_{(1,44)}$=0.78, p=0.381) and the observed power of this test was low (0.139). Furthermore, the interaction between the part of the experiment (experiment halves, questions 1–15 versus questions 16-30) and the display systems ($F_{(1,44)}$=0.06, p=0.801) was not significant and the observed power of this test was low (0.057).

As was reported earlier when analysing each between subjects factor individually, this analysis (where both between subjects factors and the within subjects factor were analysed together) also confirmed that the between subjects factors, display systems (Reality Center or 3-monitor display system) was a significant factor ($F_{(1,44)}$=5.096, p=0.029) and order of stimuli ('Music First' or 'No Music First') was not a significant factor ($F_{(1,44)}$=0.004, p=0.95). Furthermore, the interaction of these two factors was not significant ($F_{(1,44)}$=4.026, p=0.051) and the power of these tests low, therefore there is a high probability of making a Type II error in these results. The power for the within subjects factor test ('Music' vs 'No Music') was below the threshold (0.65) yet it was higher than for the other tests. On the other hand, the three-way interaction (see black solid rectangle in Table 8) between the halves of the experiment, order of the stimuli and the display systems was statistically significant ($F_{(1,44)}$=10.82, p=0.002) and the power of this test high (0.89). Thus, it was decided to investigate this result further.

Table 8: Multivariate Tests for Stimuli Order, Display Systems by Stimuli

Effect		Value	F	Hypothesis df	Error df	Sig.
Half	Pillai's Trace	.116	5.776	1.000	44.000	.021
	Wilks' Lambda	.884	5.776	1.000	44.000	.021
	Hotelling's Trace	.131	5.776	1.000	44.000	.021
	Roy's Largest Root	.131	5.776	1.000	44.000	.021
Half * DisplaySystem	Pillai's Trace	.001	.064[a]	1.000	44.000	.801
	Wilks' Lambda	.999	.064[a]	1.000	44.000	.801
	Hotelling's Trace	.001	.064[a]	1.000	44.000	.801
	Roy's Largest Root	.001	.064[a]	1.000	44.000	.801
Half * DisplaySystem	Pillai's Trace	.018	.784[a]	1.000	44.000	.381
	Wilks' Lambda	.982	.784[a]	1.000	44.000	.381
	Hotelling's Trace	.018	.784[a]	1.000	44.000	.381
	Roy's Largest Root	.018	.784[a]	1.000	44.000	.381
Half * DisplaySystem * StimuliOrder	Pillai's Trace	.197	10.816[a]	1.000	44.000	.002
	Wilks' Lambda	.803	10.816[a]	1.000	44.000	.002
	Hotelling's Trace	.246	10.816[a]	1.000	44.000	.002
	Roy's Largest Root	.246	10.816[a]	1.000	44.000	.002

As can be seen in Figure 47, the stimuli had an adverse effect in the two display systems on the mean number of facts that participants remembered correctly. The upper graph in Figure 47 shows the results for the Reality Center and the lower graph shows the results for the 3-monitor display system. On the y-axis, the mean number of facts that participants remembered correctly from the first and the second half (x-axis) of the VirSchool history lesson are shown for each of the display systems. For each display system the graph also shows which stimulus was presented to participants - 'Music' first (solid line) or 'No Music' first (dotted line). For the purposes of discussion, the interaction will be explored by examining the results separately for the two display systems.

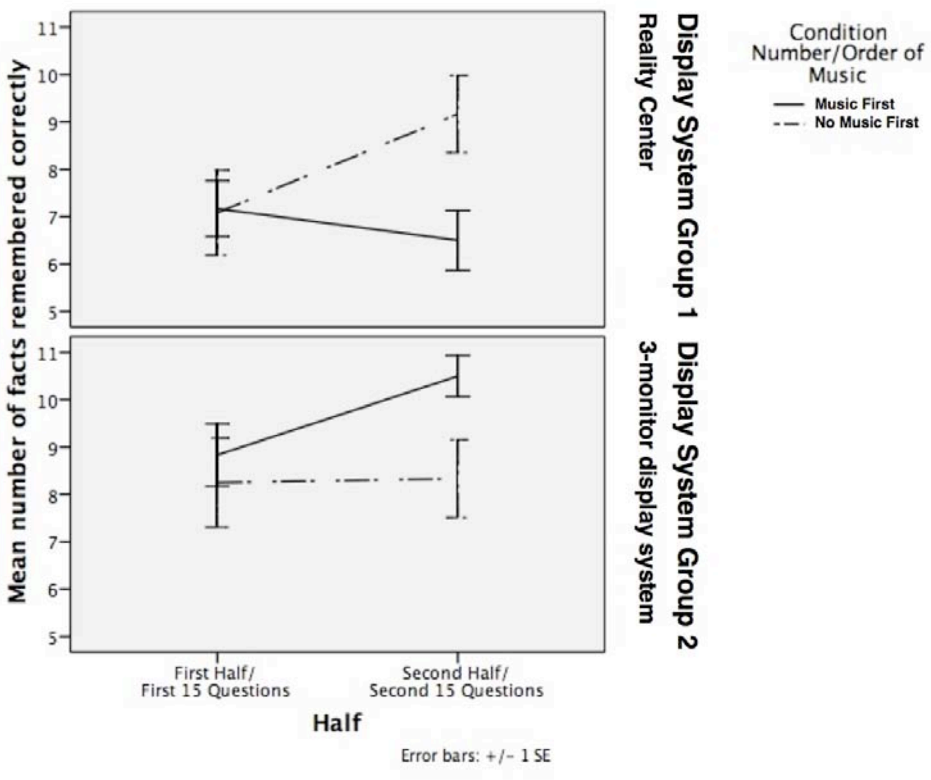
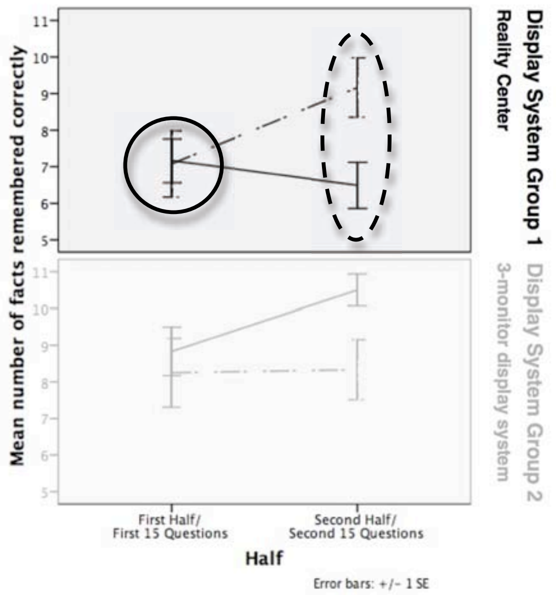


Figure 47: Mean number of facts remembered correctly from first and second half of the VirSchool history lesson compared between the Reality Centre and the 3-monitor display system with either 'Music' first (solid line) or 'No Music' first (dotted line)

To emphasise the focus on the Reality Center in the following section, the 3-monitor display system has been faded in Figure 48. As can be seen in the upper (accentuated) graph, the data shows that the mean number of facts remembered

[illegible]



Mean number of facts remembered correctly
Display System Group 1
Reality Center
Display System Group 2
3-monitor display system
Condition Number/Order of Music
Music First
No Music First
First Half/
First 15 Questions
Second Half/
Second 15 Questions
Half
Error bars: +/- 1 SE

[illegible]

[illegible]

Table 9: Pairwise comparison t-tests of Experiment Halves, Display Systems and Stimuli

ID	Experiment Condition	Mean	Std.	Mean Diffe-rence	Statistic	P value
1	First Half – Reality Center – Music First	7.17	2.04	0.08	$t_{(44)}=0.08$	p=0.941+
2	First Half – Reality Center – No Music First	7.08	3.12			
3	First Half – 3 Monitor – Music First	8.83	2.29	0.58	$t_{(44)}=0.52$	p=0.603+
4	First Half – 3 Monitor – No Music First	8.25	3.25			
5	Second Half – Reality Center – Music First	6.50	2.20	2.67	$t_{(44)}=2.72$	p=0.009#
6	Second Half – Reality Center – No Music First	9.17	2.82			
7	Second Half – 3 Monitor – Music First	10.50	1.51	2.17	$t_{(44)}=2.21$	p=0.033*
8	Second Half – 3 Monitor – No Music First	8.33	2.84			

+ Not significant

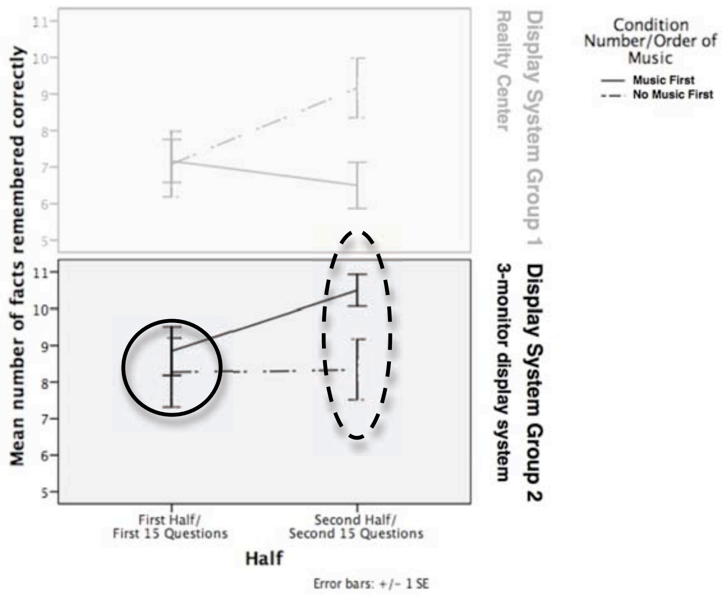
* Significant at p=0.05

Significant at p=0.01

If, however, we look at the *second half* of the VirSchool history lesson in the Reality Center (see ID 5&6 in Table 9) we see that participants from 'Stimuli Order Group 1' ('Music First') on average remembered 6.5 facts (std=2.20) correctly out of the 15 facts that were presented in the *second half* of the VirSchool history lesson. Note that 'Music first' means that participants listened to 'Music' in the first half and 'No Music' in the second half, thus, on average participants remembered 6.5 facts from the *second half* if there was no music influence (see ID 5 in Table 9). On the other hand, if participants listened to 'Music' together with the narration of the Avatar in the *second half* of the VirSchool history lesson (see ID 6 in Table 9 - 'Stimuli Order Group 2' - 'No Music First' = 'Music' in the second half), on average they remembered 9.17 facts (std=2.82) correctly from the *second half* of the VirSchool history lesson. This means that participants remembered a mean of 2.67 facts more from the facts that were presented in the *second half* of the VirSchool history lesson when they listened to 'Music' in the second half of the VirSchool history lesson in the Reality

Center. A t-test revealed that the difference between the order of the stimuli is statistically significant ($t_{(44)}$=2.72, p=0.009, <0.0125).

Until now the data analysis was focused on the Reality Center and we will now turn our analyses to the 3-monitor display system. To emphasise the focus on the 3-monitor display system, the Reality Center has been faded in Figure 49. Similar to the results from the Reality Center, the data of the 3-monitor display system (lower accentuated graph in Figure 49) shows that the mean number of facts remembered correctly in the *first half* of the VirSchool history lesson (see solid circle in Figure 49) is not different for 'Music' and 'No Music'. Looking back at Table 9 (see ID 3) we see that if 'Music' was played in the *first half* of the VirSchool history lesson in the 3-monitor display system, the mean number of facts that participants remembered correctly was 8.83 (std=2.29) on average from the *first half*. If participants were exposed to the 'No Music' stimulus in the *first half* of the VirSchool history lesson (see ID 4 in Table 9) they remembered 8.25 (std=3.25) facts correctly on average in the *first half*. This difference is not significant ($t_{(44)}$=0.52, p=0.603).


Mean number of facts remembered correctly
Display System Group 1
Reality Center
Display System Group 2
3-monitor display system
Condition Number/Order of Music
Music First
No Music First
First Half/
First 15 Questions
Second Half/
Second 15 Questions
Half
Error bars: +/- 1 SE

history lesson in the 3-monitor display system they remembered 10.5 facts (std=1.51) correctly on average from the 15 facts presented in the *second half* of the VirSchool history lesson (remember that the 'Stimuli Order Group 1' – 'Music First' means 'No Music' in the *second half*). If, on the other hand, 'Music' was played during the *second half* of the VirSchool history lesson (see ID 8 in Table 9 - 'Stimuli Order Group 2' - 'No Music First' = 'Music' in the *second half*), participants remembered 8.33 facts (std=2.84) correctly on average from the 15 facts that were presented in the *second half*. This means that participants who did **not** listen to music in the *second half* on average remembered 2.17 facts more from the *second half* of the VirSchool history lesson in the 3-monitor display system than participants who listened to 'Music'. Remember that this is the opposite result from the result that we observed for the Reality Center where listening to music in the *second half* resulted in a significantly higher average number of correctly remembered facts. On average, the difference in the number of facts remembered correctly from the *second half* depending on the stimuli in the 3-monitor display system was, however, not statistically significant at the adjusted levels ($t_{(44)}=2.21$, $p=0.033$, >0.0125).

Apart from investigating the effect of music and different display systems on learning in virtual environments, we also analysed the attitude of participants towards the virtual learning environment. One finding here is that 44 of the 48 participants answered that the virtual environment was a useful learning tool and only 4 participants thought that it was not useful (see Table 10) - That is an overwhelming 91.7% of participants who had a positive attitude towards the virtual environment (versus 8.3% who had a negative attitude).

Table 10: 44 of the 48 participants thought that the virtual environment (VE) was a useful learning tool. 4 thought it was not useful.

VE useful learning tool

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	4	8.3	8.3	8.3
	Yes	44	91.7	91.7	100.0
	Total	48	100.0	100.0	

The obvious question is, whether this positive attitude towards the learning environment is reflected in participants' performance in the memory task. A direct analysis compares participants' attitude towards the virtual learning environment with the total number of questions answered correctly.

As we can see in Table 11, those participants who thought that the virtual environment was a useful learning tool on average remembered 2.68 facts more than those who did not think that the virtual environment was a useful learning tool. However, these results are not statistically significant ($p=0.3$) and this might be due to the small number of 'non-likers' of the virtual environment (4 participants).

Table 11: Those participants who indicated that the virtual environment (VE) was a useful learning tool remembered 2.68 facts more than those who indicated that the virtual environment was not a useful learning tool

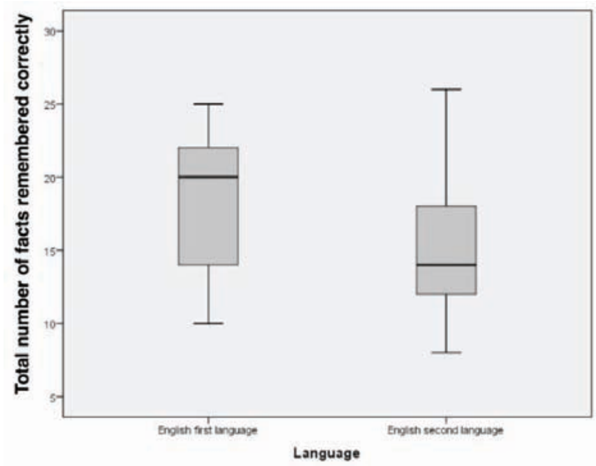
Total NOFRC

VE us...	Mean	N	Std. Deviation
No	14.00	4	4.830
Yes	16.68	44	4.893
Total	16.46	48	4.894

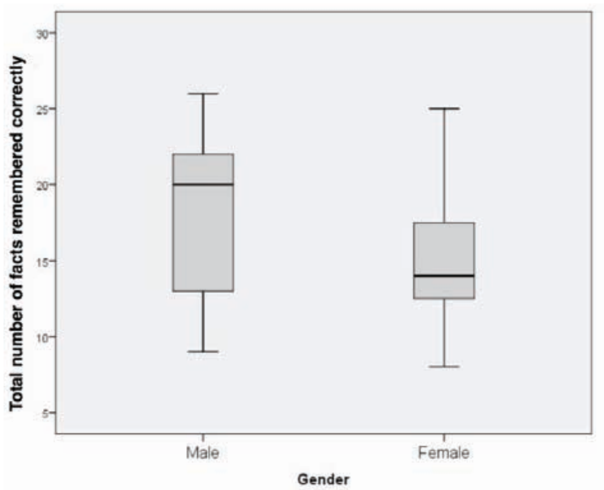
On the other hand this result cannot be viewed by itself but rather has to be seen in conjunction with the results that were observed for the same question in Experiment 1. Looking at the results from Experiment 1 we find that the results were statistically significant ($p=0.046$). However, the choice to answer this question had been changed from a 5-point Likert scale to a Yes/No question because the answers in the first experiment were too varied and it was hoped to get more meaningful answers by changing the response type. In retrospect, it seems that it would have been better to leave the response type as a Likert scale in order to allow a direct comparison with the data of Experiment 1.

Another observation was that those participants who felt that the music assisted their learning were more likely to positively answer the question if they thought that the virtual environment was a useful learning tool at statistically significant level ($p=0.001$). Moreover, 65% of participants liked the part with background music more, compared to 35% of participants who preferred the part without background music irrespective of whether it was played during the first or second half of the VirSchool history lesson and disregarding the type of display system in which they were watching the VirSchool history lesson.

Furthermore, we found that participants who indicated English as their first language (37.5%) on average remembered 3.1 more facts ($t_{(46)}=2.202$, $p=0.033$) than participants who indicated English as their second or other language (see Figure 50). Descriptive statistics (see Table 13 in Appendix E) show that language or gender could not be included as between subjects factors to the repeated measures analysis because there were too few observations in each cell if they were added as between subjects factors in addition to the existing between subjects factors.



Total number of facts remembered correctly
30
25
20
15
10
5
English first language
English second language
Language



Total number of facts remembered correctly
30
25
20
15
10
5
Male
Female
Gender

4.2.6 Discussion

Experiment 2 investigated the significant findings from Experiment 1 further by taking into account the variables that were beneficial for memory in Experiment 1 (tempo, pitch, musical piece). The experiment design was changed from a 'Between Subjects Design' (Experiment 1) to a 'Repeated Measures Design' (Experiment 2) with one within subjects factor (Music, No Music) and *one* between subjects factor (Stimuli Order Groups). Thus, we aimed to draw more powerful conclusions from the results by comparing 'Music' versus 'No Music' in the Reality Center. However, this design had to be changed to a 'Repeated Measures Design' with one within subjects factor (Music, No Music) and *two* between subjects factors (Stimuli Order Groups, Display System Groups) half way through the experiment because of equipment failure. Regardless of the equipment changes, the questionnaire had been adapted earlier to satisfy new requirements that became apparent after the VirSchool history lesson was separated into two halves (first half, second half). The number of questions for each half of the VirSchool history lesson was adjusted accordingly in the questionnaire for Experiment 2. Following is a summary of our findings.

1. First, we found a significant correlation ($r=0.568$, $p<0.0005$) but no statistically significant difference between the 'Music' and 'No Music' conditions across display systems and stimuli order groups ($t_{47}=0.779$, $p=0.44$).
2. Secondly, when we compared the mean difference of the number of facts remembered correctly between the 'Music' and 'No Music' conditions in two display systems, we found a statistically significant effect ($t_{46}=-2.209$, $p=0.032$) that favoured the use of the 3-monitor display system.
3. Furthermore, we found that on average participants remembered significantly more facts correctly in the second half of Experiment 2 as

compared to the first half ($F_{(1,46)}$=4.78, p=0.034), regardless of display systems and stimuli, although this was a relatively small effect size (eta-squared = .09). The between subjects factor (Reality Center or 3-monitor display system) was a significant factor ($F_{(1,46)}$=4.88, p=0.032). Furthermore, the power of this analysis was less than 0.80, thus, we do not have adequate power to assume no Type II error was made.

4. A comparison of results of the 'No Music' condition between display systems showed that on average participants in the 3-monitor display system remembered significantly more facts correctly than their peers in the 'No Music' condition in the Reality Center ($t_{(46)}$= -3.32, p=0.002).
5. In contrast, no statistically significant difference could be detected between the 'Music' condition in the Reality Center and the 3-monitor display system (t_{46}= -0.56, p=0.578).
6. Overall, when combining results from the display systems and when using musical condition ('Music', 'No Music') as a within subjects factor, it was again found that on average participants remembered more facts correctly from the second half of the VirSchool history lesson ($F_{(1,46)}$=4.84, p=0.033) confirming the results from item 3 in this list, although this was a relatively small effect size (eta-squared = .09). The between subjects factor, stimuli order ('Music First', 'No Music First'), however, was not a significant effect ($F_{(1,46)}$=0.003, p=0.954). Furthermore, the power of this analysis was very low, thus, we do not have adequate power to assume no Type II error was made.
7. When comparing the order of the stimuli ('Music First' or 'No Music First') across display systems, the order of the stimuli was not a significant effect (p>0.05) and the power of this test was low. Thus, the probability of making a Type II error was high.
8. When separating this comparison between display systems it was found that on average in the Reality Center participants remembered significantly more facts correctly in the second half of the VirSchool

history lesson. In the 3-monitor display system this comparison of the mean number of facts remembered correctly was in the hypothesised direction (more facts remembered from the second half than the first half) but not statistically significant.

9. A three-way interaction between the halves of the experiment, order of the stimuli and the display systems was highly statistically significant ($F_{(1,44)}$=10.82, p=0.002) and the power of this test high (0.89). Thus, it was decided to investigate this result further.
10. It was found that the stimuli in fact showed an adverse effect in the Reality Center and the 3-monitor display system. On average, participants who listened to 'Music' in the second half of the VirSchool history lesson in the Reality Center remembered statistically significantly more facts than those who did not listen to music in the second half of the VirSchool history lesson in the Reality Center ($t_{(44)}$=2.72, p=0.009, <0.0125).
11. Contrary to this, on average, in the 3-monitor display system those participants who did not listen to music in the second half of the VirSchool history lesson remembered more facts correctly from this second half than their peers who listened to music in this half. This effect was, however, not statistically significant ($t_{(44)}$=2.21, p=0.033, >0.0125) in the 3-monitor display system.
12. Furthermore, we found that 91.7% of participants thought that the VirSchool history lesson was a useful learning tool, however, this positive attitude had no effect on the mean number of facts they remembered correctly from the VirSchool history lesson (p=0.3).
13. In addition, those participants who felt that the music assisted their learning were more likely to positively answer the question if they thought that the virtual environment was a useful learning tool at statistically significant level (p=0.001).
14. Sixty-five percent of participants preferred the part with music in the VirSchool history lesson.

15. Furthermore, we found that participants who indicated English as their first language (37.5%) on average remembered 3.1 more facts ($t_{(46)}$=2.202, p=0.033) than participants who indicated English as their second or other language. However, not enough data was available in some cells to use this variable as an additional between subjects factor in previous analyses.
16. On average, male participants remembered more facts ($t_{(46)}$=2.16, p=0.036) from the VirSchool history lesson than female participants.

Looking at this summary, our analysis of the Experiment 2 data contradicted the result from Experiment 1 (see item 1 in above summary) that the manipulated musical piece (slower tempo, lowered pitch) from the Oblivion soundtrack had an overall beneficial influence on participants' memory. However, other results showed that data analysis was more complex than simply comparing 'Music' with 'No Music' across conditions. This became clear when the results between the two different display systems (Reality Center, 3-monitor display system) were compared and a statistically significant effect was revealed that favoured the use of the 3-monitor display system over the Reality Center (see item 2 in above summary). Additionally, on average, participants remembered more facts correctly from the second half (see item 3 in above summary) in both display systems (although the power of this result was low) and participants in the 'No Music' condition in the 3-monitor display system remembered more facts correctly than their peers in the same condition in the Reality Center (see item 4 in above summary). No statistically significant difference could be detected for the 'Music' condition between display systems (see item 5 in above summary). Further analyses showed that the order in which stimuli were presented to participants had no significant effect on the mean number of facts remembered correctly in the two halves (see item 6 in above summary) although the power of this test was low. Moreover, the order of the stimuli ('Music First' or 'No Music First') across display systems was not a significant factor (see item 7 in above summary), however, when investigated separately, it was found that on average participants in the Reality Center remembered statistically significantly more facts in the second half than in the first half (see item 8 in above summary). However, the same analysis was not significant for the 3-monitor display system. Most notably, a highly significant three-way interaction was revealed between the mean number of facts remembered correctly from the two halves of the VirSchool history lesson, the stimuli order and the two display systems (see item 9 in above summary). Closer analysis of the data showed that participants in the Reality Center remembered more facts correctly on average if they were listening to music in the second half of the VirSchool history lesson as compared to their peers in the same display system who did not listen to music in the second half (see item 10 in above summary). This result stands in contrast to the results from the 3-monitor display system in which on average those participants who listened to music in the second half of the VirSchool history lesson remembered less facts correctly than their counterparts who did not listen to music in the same display system (see item 11 in above summary). The remaining findings showed that participants liked the VirSchool history lesson (see item 12 in above summary) but this preference had no influence on the number of facts they remembered correctly (see item 13 in above summary). Moreover, 65% of participants enjoyed the part with music more than the part without (see item 14 in above summary). Furthermore, we found that on average participants who indicated English as their first language remembered significantly more facts than those who answered that English was their second or other language (see item 15 in above summary), however, numbers in the different cells of this result were too small for further analyses. Lastly, we found that on average male participants remembered more facts from the VirSchool history lesson than female participants (see item 16 in above summary).

An explanation for this latter finding could be that the majority of female participants (70.4%) indicated English as their second or other language, compared to 50% of males who indicated English as their second or other language. Thus, it may be that the language barrier was the true reason why on average female participants remembered fewer facts correctly than their male counterparts. However, we report only a preliminary result at this point because, as was said before, the observations in each cell for the language factor were too few for some cells to warrant further investigations. Also, based on the unexpected results that followed the separation of the data between display systems for the 'Music' vs. 'No Music' conditions, it might also be possible that opposite results would be found for genders depending on the display system or whether participants watched the VirSchool history lesson with background music or without background music. Furthermore, the mean difference of the number of facts remembered correctly between males and females might have other reasons altogether and as with the other findings that were not directly related to the primary research question of this thesis, we have to leave the investigations and confirmation or rejection of this result to other researchers whose research question is more related to this phenomenon.

When we turn our attention back to the effect that on average participants in the Reality Center performed worse than their peers in the 3-monitor display system, one possible explanation for this result could be that participants in the Reality Center were overloaded with incoming stimuli in the unfamiliar and visually overwhelming display system, however, it should be noted that the initial experiment was not designed to test for such possible cognitive overload and that the unforeseen contradictory results between the display systems had only been discovered after the equipment failure forced us to introduce the 3-monitor display system as a less immersive display alternative. Thus, a further review of the literature was necessary to find a possible explanation for the observed effect.

A display system that has a wider field of view is accepted to be more immersive than another display system with a narrower field of view (Slater *et al.*, 2002, p. 23). In the present study the Reality Center would thus be categorised as being more immersive than the 3-monitor display system. However, as others have investigated, immersion is related to the feeling of presence (Slater *et al.*, 2002, p. 24) but not necessarily related to improved learning (Moreno *et al.*, 2002; Persky *et al.*, 2009). Moreno and Mayer (2004), for example, report that in their experiments "there was [...] no support for the idea that higher levels of immersion free up cognitive capacity that can be used for active cognitive processing during learning" (Moreno *et al.*, 2004, p. 171). They further state, "one possible explanation is that the higher level of immersion induced by the HMD [Head Mounted Display used in their experiments] distracted the learner from paying attention to the academic content of the game" *(ibid.)*. Furthermore, Sharples *et al.* (2008) report from their experiments, where they used different types of display systems with different levels of immersion (a single monitor display, a head mounted display, a Reality Center or a wall projection system), that "the monitor display had much more acceptance with participants as they were familiar with using it in a normal working environment." (Sharples *et al.*, 2008, p. 59). In the situation of the VirSchool history lesson the question is therefore, whether the unfamiliarity and overload with new stimuli in the highly immersive Reality Center were in fact counterproductive to the learning effect of participants and cognitive overload was the reason why they performed worse than their peers in the 3-monitor display system.

Sweller (1988), for example, reports about the restrictions of human working (i.e. short-term) memory when it comes to the processing of incoming stimuli. He reports that when the number of items that are to be stored and processed in working memory becomes too large, the result is a cognitive overload which in turn leads to a decrease in the performance of the original task *(ibid. p. 275)*. This theory goes along the same line of George Miller's finding which shows that the capacity of our working memory is 7 ± 2, which means that our brain can keep between 5 and 9 pieces of information in working memory at the same time (Miller, 1956). Although Sweller has tested his 'Cognitive Load Theory' with a focus on problem solving tasks, it seems reasonable that the underlying restrictions of the human brain apply to the present situation of the Reality Center and the embedded background music as well. Additionally, when Keith (2006) reports about high drop out rates of distance students in eLearning he states that if learners have not yet developed a schema in long term memory to which new information can be linked, they are easily overwhelmed or overloaded by the new and different learning methods of the eLearning process. He states "this overloading can result in a learner becoming highly anxious and losing confidence, which in turn can lead to the learning process, in effect, freezing and the learner being unable to continue" (Keith, 2006, p. 78). This explanation is further supported by Clarke *et al.* (2005) who found that teaching students a spreadsheet application while at the same time teaching them mathematics reduced their performance in the mathematics tasks. They recommend that the curriculum area should be learned serially rather than simultaneously. Thus, if participants were intimidated or overwhelmed by the unfamiliar display system it may be that their working memory was overloaded and not capable of processing as much information from the VirSchool history lesson as participants in the more familiar 3-monitor display system. This possible explanation is further supported by Sweller (see personal conversation, Appendix F) who states that this explanation seems plausible but he doubts that there is any literature on it.

Further evidence for the detrimental effects of cognitive overload comes from the Attention Deficit Hyperactivity Disorder (ADHD) research area where some researchers (Hartmann, 2003; Restak, 2004; Rizzo *et al.,* 2000) - argue that the root cause of ADHD is the oversupply of information that comes with the plethora of emerging technology. The reasoning behind the claims of Hartmann, Restak and Rizzo is that in today's world we are constantly distracted by a new flash of information coming to our minds and that we are therefore no longer able to concentrate on a single task anymore. Restak also talks about multi-tasking when he refers to two or more tasks that require the attention of the same brain area. He states that humans are well able to do two things at the same time as long as they do not interfere with each other. However, despite the claim that ADHD is an attempt of our brain to handle all the incoming information, Restak states that actually our brain works best when we are focussing on one task at a time. Any sort of distraction reduces efficiency *(ibid. p. 67)* and should be avoided. He writes:

> *Actually, multi-tasking is not nearly as efficient as most of us have been led to believe. In fact, doing more than one thing at once or switching back and forth from one task to another involves time-consuming alterations in brain processing that reduce our effectiveness at accomplishing either one. […] And, most importantly, these shifts decrease rather than increase your efficiency; they are time and energy depleting. (Restak, 2004, p. 65)*

Whether it is the results from the immersion research, cognitive load research or the problems that have been identified in relation to multi-tasking, all areas show that the human brain does not perform well if too many stimuli have to be processed at the same time. Thus, it could be that in our experiment participants in the Reality Center were unfamiliar with such an immersive display system and would therefore feel overwhelmed and consequently less comfortable. This unfamiliarity and reduced level of comfort in turn could explain the reduced memory performance, similar to participants in the surgeons experiment where those participants who were allowed to bring their own music performed significantly better than those participants who listened to investigator-selected music (Allen *et al.*, 1994). Although there is support from the literature for our attempt of an explanation, the further investigation of this unexpected result would have gone beyond the scope of the research question. However, this possible explanation may offer a starting point for further investigations.

In the present situation the result of a statistically significant difference between the two display systems, however, revealed that in order to answer the research question, data analysis had to be separated for the Reality Center and the 3-monitor display system. After separation of the data from the two display systems data analysis showed that the stimuli ('Music' and 'No Music') were involved in a significant three-way interaction together with the display systems and depending on from which half of the VirSchool history lesson (first five and a half minutes vs. second five and a half minutes) questions were asked.

In the Reality Center, on average, participants remembered more information from the second half of the VirSchool history lesson when they were presented with background music ('Music' condition) in the second half of the VirSchool history lesson. Correspondingly, if participants listened to the narrator without background music ('No Music' condition) in the second half of the VirSchool history lesson, on average, they remembered less information from the second half of the VirSchool history lesson.

If the absence of music in the second half would have made participants remember more of the information, then this observation would have been the same in both display systems, however, this was not the case for the 3-monitor display system, on average. If participants *heard no music* in the second half in the 3-monitor display system, on average, they remembered *more* from the information in the second half. In the Reality Center on the other hand, on average, participants remembered more information from the second half if they *did hear music* in the second half. Thus, the reason for the better memory of participants could neither be the music nor the absence of music in the second half. Therefore, it was necessary to examine the data more closely and analysis of the results from the first half of both display systems showed that the mean number of facts remembered correctly was not significantly different whether participants listened to music or whether they did not. In fact, the mean number of facts remembered correctly was almost identical in the first half of the VirSchool history lesson for each display system. One explanation for the discrepancy of the mean number of facts remembered correctly from the second half between display systems could be that the facts in the second half were easier to remember, however, this would mean that we would have observed this effect equally for both display systems, which we did not. Another possible explanation could be a carry-over effect in which the stimulus presented to participants in the first half of the experiment affected their performance in the second half. This carry-over effect, however, would have to be the same in the two display systems as well, which it was not. Thus, the differing results of 'Music' and 'No Music' in the second half of the different display systems remains unclear.

At this point we want to take the findings from the cognitive load theory Sweller (1988, 2003) and the " Magical Number Seven, Plus or Minus Two" (Miller, 1956) into account again and suggest that maybe music in the first half of an already visually overwhelming display system could have added to the cognitive load of participants. This 'double' cognitive overload (display system *and* music) could be the reason why participants 'switched off' and thus were not able to remember information, even from the second half when the music was removed. On the other hand if participants did not hear music in the first half and were only confronted with the extra cognitive load of the new and unfamiliar Reality Center display system, the cognitive load was lower than for their peers who heard the music in the first half. However, even if this interpretation would explain the observed results in the Reality Center, we are still left with the opposite observation in the 3-monitor display system.

For the 3-monitor display system, however, there might be another explanation that has less to do with cognitive load but instead could be explained with the level of comfort of the participants which might be higher in the smaller arrangement of the 3-monitor display system. No support for this claim could be found in the literature, but at this point it should be mentioned that after observing 96 participants in the Reality Center, the author of this thesis instantly observed a change in how participants approached the task as soon as the first participant began the experiment when using the 3-monitor display system instead of the Reality Center. It seemed that participants were much more comfortable and relaxed with the smaller sized 3-monitor display system than with the physically and technically overwhelming Reality Center. The reason for this improved 'comfort zone' might be that a 3-monitor display system is only one or two levels above the technological equipment that participants are used to in their homes (three monitors instead of one or two) as compared to the many levels that a Reality Center is away from the technological status quo of normal citizens (i.e. non-virtual-environment-researchers). Secondly, when participants approached the task in this environment and there was music present in the first half of the VirSchool history lesson, this music could have been interpreted by participants as being 'normal' in a video game environment[73], similar to film music, which is almost expected in contemporary movies. In this more comfortable environment music might in fact have a similar effect as the K448 Sonata used in the experiments of Rauscher *et al.* (1993) where those participants who listened to 10 minutes of Mozart *before* the experiment scored 8 – 9 points higher in a subsequent spatial ability IQ test. Also, when we recall the findings from Allen *et al.* (1994) they report that surgeons regularly use music to block out distractions when operating. Thus, in a familiar environment the music might in fact help people to disconnect from the outside world and their problems and help them to concentrate on the task at hand. If, however, no music was played at the start of the VirSchool history lesson in the

[73] From a researchers perspective it is a virtual environment but to a member of the general public the VirSchool history lesson would look like a video, especially since it uses video game technology to create the virtual environment.

3-monitor display system, participants might have consciously or unconsciously recognised that an essential element of a normal video game was missing and thus they did not get as absorbed into the virtual environment as in a typical video game. It should be explicitly noted that this explanation has not been confirmed in the present data analyses and no support could be found in the literature except for the possible connections to the findings of Rauscher et al. (1993) and Allen *et al.* (1994), which were in other research areas. However, this possible explanation may offer a starting point for future investigations.

Returning to the situation of the author's friend playing World of Warcraft on a wall-projected display system, the question comes to mind whether he would have experienced any cognitive overload from playing on this display system and listening to background music at the same time, or not. The answer would most likely be that he was not experiencing such cognitive overload with the reason being that this situation/gaming environment was desired and purpose-built by the player himself. Thus, the author's friend was familiar with the technology and felt comfortable with the setup. The music would have helped him to disconnect from the outside world and concentrate on the tasks in the computer game environment. He would have not had to process any new, unfamiliar stimuli.

5

CONCLUSION

Eighty eight per cent of Australian homes have a device for playing computer or video games and 68% of Australians play computer or video games (IEAA, 2009). Despite these impressive numbers and although corporations, governments and more recently educators are using virtual environments and computer games for teaching and training purposes, very few studies in fact investigate the effectiveness of teaching in these virtual environments. The existing literature shows that there are some positive and negative aspects of playing video games. The many positive aspects include the possibility to learn about political and medical situations, experience teamwork and practice leadership and to train character development. On the down side, the negative aspects include possible exposure to violence and sexually explicit content, which might not be appropriate for the announced target audience. However, this is the point where it becomes important for us as teachers to create the content that we would like our students to learn. Furthermore, if we want forthcoming generations to learn the information and values that we envisage to be the best for their future, we have to make use of the technology that the younger generation uses on a daily basis to get them involved and motivated in the learning process. Since students of any age enjoy playing video games and exploring virtual environments, these might be the ideal media to capture their attention. Furthermore, music offers a possibility to attract students to new teaching environments. However, attracting students to new forms of teaching environments cannot be the sole motivator, instead it has to be investigated whether these new teaching environments and music in fact helps students to improve their learning. Therefore, the research of the effect of music on memory and learning in virtual environments is an important investigation if we want to define parameters that support the creation of useful virtual environments for future teaching and training purposes.

5.1 Summary and Outcomes

One way of creating such contemporary teaching environments is to use existing video game technology and develop virtual environments that offer deep and meaningful, holistic learning experiences. However, since there are very few virtual learning environments like the one used in this study, in future investigations it might be easier to use commercially available video games, because video games are used by a wider target population[74] than such specific virtual environments like the one used in this study. Thus, results might be more generalisable. Saying that, maybe the results from this study are not that far away from being transferable to the domain of video games. If we recall the definition of 'Virtual Reality' from section 2.3.7, video games are in fact closer to being a true 'Virtual Reality' than the Virtual Environment used in the present study because video games feature interactivity, which the VirSchool history lesson does not. According to Sherman's definition of Virtual Reality (Sherman *et al.*, 2003, p. 6) an interactive, immersive game that features a virtual world and additionally gives sensory feedback (such as the orientation of where the gaming device is pointing in an Augmented Reality game on, for example, the iPhone 3GS[75] with its compass and global positioning system), would have to be termed a Virtual Reality. Thus, virtual environments and video games are not too different and results from this research might, under certain circumstances, be transferable to the domain of video game based teaching. However, again, this would have to be confirmed by further investigations.

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[74] The results of this study were achieved in a virtual learning environment rather than a video game, thus inferences from one category (virtual learning environment using video game technology) to the other (video games) would have to be confirmed by other experiments.

[75] http://www.apple.com/iphone/, last accessed: 10.08.2009

Also, the visual, computer-animated part of educational video games/virtual environments is only one side of the coin. The other, often overlooked, part of video games and virtual environments are the sound effects and music that are played throughout these games. Just like in movies, it is this subtle soundscape that often adds another dimension to the virtual environments and makes them more attractive to players. Yet, very little research exists that investigates the role of music and its effect on cognitive processes inside these environments. It was this gap in the existing body of knowledge that motivated the author of this thesis to investigate whether music supports memory of people who use a virtual environment for learning historical dates and facts.

Because of the lack of literature about this very specific topic, literature of associated research areas was reviewed. It was found in the literature of these associated research areas, that music can have beneficial effects on certain cognitive functions if chosen appropriately. For example, surgeons perform better in a backward counting task when listening to music (Allen *et al.*, 1994) and participants in a maze task experiment performed significantly better when listening to music on the ear that was opposite to the hand they were using to solve the maze task (McFarland *et al.*, 1988). This experiment further showed that two tasks performed within the same brain half (listening to music, performing the maze task) competed for processing power of the brain. On top of this already fascinating finding, this experiment also showed that if participants were listening to music in both ears their maze task performance improved even further. This demonstrated, that instrumental music keeps the right brain half busy and thus frees the left brain half from communication with the right brain half which in turn frees up processing power of the left brain half for other tasks. The 'Mozart Effect' seemed to support this claim (Rauscher *et al.*, 1993), however, it was later found that arousal and mood may be the crucial aspects that led to improved spatial-temporal performance (Thompson *et al.*, 2001).

Furthermore, it was found that music has a beneficial effect on motivation in language learning games (Weisskoff, 1981) and if music is congruent with scenes in a movie, remembrance of those scenes is higher than with incongruent music (Boltz *et al.*, 1991). The few studies that have been found about the effect of music played during video games (Alin *et al.*, 1987; North *et al.*, 1999; Yamada, 2002) showed inconsistent results and did not directly address memory as a topic. Thus, it was necessary to collect new data and after careful consideration of available research methods, it was decided to take an experimental approach for these investigations.

Therefore, a computer-animated history lesson, the VirSchool, was developed in which background music stimuli were controlled and exchanged. The first set of experiments used a Reality Center and music stimuli were manipulated in tempo and pitch. Participants were recruited from a general student population and answered questions about biographical data, the historical content of the VirSchool history lesson, immersion and previous experiences with video games and music. The results from this experiment showed that slow music at a reduced pitch had beneficial effects on memory for facts from the VirSchool history lesson. Furthermore, the influence of one particular soundtrack showed a statistically significant effect on participants' memory as compared to a 'No Music' condition.

The results from this first experiment were used in the design of a second experiment. Experiment 2 used the Oblivion soundtrack (which produced statistically significant results in Experiment 1) and reduced its tempo and pitch. Furthermore, the experiment design was changed from a 'Between Subjects Design' to a 'Repeated Measures' design with one within subjects factor ('Music', 'No Music') and one between subjects factor (Stimuli Order) to allow more powerful data analysis. In the new design, each participant received a 'Music' condition and a 'No Music' condition, therefore, participants acted as their own control group. Experiment 2 also split the VirSchool history lesson into two halves and questions about the content were adjusted accordingly. Additionally, a second (3-monitor) display system was introduced due to equipment failure of the Reality Center that was used in Experiment 1 and was planned to be used in Experiment 2 as well. Consequently, the experiment design changed from a repeated measures design with one within subjects factor ('Music', 'No Music') and one between subjects factor (Stimuli Order) to a repeated measures design with one within subjects factor ('Music', 'No Music') and two between subjects factor (Stimuli Order, Display Systems). Thus, half the participants in Experiment 2 used the less immersive 3-monitor display system.

Data analysis of Experiment 2 revealed that the less immersive 3-monitor display system overall produced statistically significant better results in terms of the mean number of facts that participants remembered correctly from the historical facts of the VirSchool history lesson. This result showed that the analysis of the remaining data had to be separated for the two display systems. Upon closer examination of the data it became clear that a significant three-way interaction existed between the display systems, the two halves of the VirSchool history lesson and the order in which the stimuli ('Music', 'No Music') were presented to participants.

Data analysis from the two display systems showed that listening to 'Music' or 'No Music' in the first half did not have any effect on the mean number of facts participants remembered correctly from the first half in either of the display systems. However, if music was played during the second half of the VirSchool history lesson in the Reality Center a statistically significant beneficial effect on participants' remembrance of facts from the second half of the VirSchool history lesson was observed. Surprisingly, the opposite effect was found for the 3-monitor display system. If music was played in the second half of the VirSchool history lesson in the 3-monitor display system, on average, participants remembered less of the information from this second half. The observation in the 3-monitor display system was, however, not statistically significant.

It is argued, that the reasons for this adverse finding are that in the Reality Center the amount of technology and visual impressions overwhelmed participants. If in this environment music was played right from the start it contributed to cognitive overload that participants already experienced due to the unfamiliarity with the Reality Center. Consequently, it could be that participants were not able to concentrate on the subject matter and had less processing capabilities to encode the facts from the VirSchool history lesson. On the other hand, in the 3-monitor display system music may have acted as a primer to immerse participants into the virtual environment and help them disconnect from the outside world and concentrate on the subject matter, which in consequence may have helped them to remember more information from the second half of the VirSchool history lesson.

Finally, the research question should be answered.

> *Does background music in immersive virtual environments affect human memory of facts that are conveyed in such immersive virtual environments?*

From the discussion and explanations above it becomes clear that the answer to the research question is more complex than a straightforward 'Yes' or 'No'. Many factors influenced the results of the experiments; in fact, it was this complexity that was the most challenging part of this research project. From Experiment 1 it seemed as if at least one soundtrack had been identified that showed a beneficial and statistically significant influence on participant's memory. The fact that we did not find confirmation of this result in Experiment 2 put the results from Experiment 1 and the hypothesis that instrumental music at slow tempo and lowered pitch facilitates learning in virtual environments, into question. Only by considering the differences between the two experiments and upon close examination of the data from Experiment 2 could a suggestion for the reason for this inconsistent result be made (see below list). Moreover, some unexpected side effects were discovered and as a result of this in-depth data analysis, the answer to the research question and hypothesis is manifold. Following are the answers that we found and when we use the term 'Music' in these answers, we refer to slow tempo, instrumental background music, as was used in the experiments of the present study. Furthermore, when we use the term VirSchool history lesson we refer to the virtual environment that was created for the present study and that used the history of the Macquarie Lighthouse to test memory for facts about the lighthouse. The answers are -

For the Reality Center:

1. *Yes, music played in the second half of the VirSchool history lesson in the Reality Center improved memory for facts presented in the second half of the history lesson as compared to not listening to music in the second half.*

2. *No, music played in the first half of the VirSchool history lesson in the Reality Center did not improve memory for facts presented in the first half of the history lesson as compared to not listening to music in the first half.*

For the 3-monitor display system:

3. *No, music played in the second half of the VirSchool history lesson in the 3-monitor display system did not improve memory for facts presented in the second half of the history lesson as compared to not listening to music in the second half.*

4. *Not listening to music in the second half of the VirSchool history lesson in the 3-monitor display system improved memory for facts presented in the second half of the history lesson as compared to listening to music in the second half, but not at a statistically significant level.*

Normally, item 4 would not be mentioned in this list of answers because it was not a significant effect and this is the reason why we do not answer this question with a 'no'. However, because the effect that was observed was in fact contrary to the effect observed in the Reality Center it seems relevant to mention it at this point in order to take this observation into consideration for future experiments.

Apart from the answers to the research question we found that

5. *The use of the 3-monitor display system resulted in better memory for facts from the VirSchool history lesson compared to using the Reality Center.*

Additionally, we propose the following explanations for the observed effects in the Reality Center and the 3-monitor display system

6. *The reason for the reduced effectiveness of the Reality Center may be cognitive overload due to the novelty and overwhelming effect of this display system.*

7. *The 3-monitor display system may not create cognitive overload (in contrast to the Reality Center) because it is an environment that could be more familiar to participants.*

8. *Thus, listening to music at the beginning of the VirSchool history lesson in the 3-monitor display system may have helped participants to shut off external distractions and concentrate on the task at hand.*

On the basis of the results presented and findings from existing literature in adjacent research areas, a number of recommendations can be made regarding the use of different display systems and background music for the purpose of using virtual environments as teaching tools.

First, we conclude that the use of a 3-monitor display system is to be preferred over a Reality Center for visual presentation of a virtual teaching topic. Secondly, it is recommended to use instrumental music at a slow tempo with low pitch, to accompany a virtual teaching topic. This music should be congruent to the virtual environment and the presented teaching matter, to achieve the most beneficial effect. Note that our suggestion is to ideally *compose* a congruent soundtrack at a slow tempo and with a low pitch rather than taking an existing soundtrack and lowering it in tempo and pitch. Furthermore, it is advisable to introduce the background music at the beginning of the virtual teaching topic, if using a 3-monitor display system. On the other hand, if it is decided to use a Reality Center for teaching purposes, music should be introduced after an initial time of allowing participants to get accustomed to the Reality Center. Additionally, it should be recalled that although two thirds of participants indicated that listening to the background music was beneficial to their learning, one third indicated the opposite. This means that developers of virtual learning environments would probably be best advised to offer an option of turning the background music on or off. By offering this option, users will have the choice of having the background music or not, based on their personal preference.

5.2 Limitations

The results from this study are attained from a very specific virtual environment teaching scenario. Thus, the above recommendations should be viewed in this context and the highest likelihood of similar results will be found in comparable environments. However, the results aim to spark further research in this area and stimulate discussion about best practices in combining new technologies and proven teaching techniques. If such a discussion develops, more research will be conducted in the area of the effect of music on cognitive functions of the brain in virtual environments and further results from other researchers might form a more generalisable picture and a more comprehensive understanding of how music in virtual environment teaching lessons and video games can support learning.

We have already acknowledged the limitation of a clinical and artificial experiment environment in section 3.1 and in future experiments a group of participants could be left with the choice of which display system they want to use and another group would be randomly assigned to a display system, like in the present experiments. Data analysis would then give insight into whether personal preference for a particular display system results in better performance in a memory task. Moreover, a pure memorisation task like the one in the present experiments is a rather untypical situation for students who usually have to relate new information to already existing information in order to understand them in context (Sweller, 2003, p. 218). Thus, a more interactive, learner centred approach would be advisable for future research. Additionally, future research could eliminate the language problems of the present experiments by only recruiting participants whose first language is that of the teaching matter.

Furthermore, we cannot draw conclusions for the general population because sample sizes were small for both experiments and participants were not randomly selected from the target population, instead, they self-selected themselves for the experiments. In addition, university students are not a representative group of the general population because they are usually younger than the general population and most likely come from a medium to high socioeconomic class.

5.3 Future Research

This thesis has answered some questions about the effect of music on learning in immersive virtual environments. However, it has also raised further questions, especially in regards to participants' statistically significantly different performance in the two display systems. One possible explanation for participants' better performance in the 3-monitor display system may be that they were more comfortable and familiar with the desktop setup than with the overwhelming, unfamiliar Reality Center. Isen (1987, 2001, 2004), for example, reports that affect (e.g. positively influenced by gifting participants with a small bag of candy before experiments) influences cognitive performance of participants. Although her research focuses primarily on the effect of affect on decision making and problem solving, there might be similarities to the present study. If in the present scenario participants were unsure or overwhelmed by the unfamiliar situation of the Reality Center (negative affect) this could be the reason why on average they performed worse than their peers in the 3-monitor display system. However, this is only one possible explanation and there is no data available from the present experiments to support this argument. Thus, in future studies, it would be interesting to investigate whether, similar to Isen's findings, the perceived level of comfort in the two display systems is reflected in participants' task performance. Apart from the question whether participants' familiarity and level of comfort with a Reality Center and a 3-monitor display system affects their memory performance, a comparison between a 3-monitor display system and a standard 1-monitor display system should be conducted to investigate whether it is really necessary to invest in a 3-monitor display system or whether the standard setup in a home or office environment would work just as well. Richards *et al.* (2009) have investigated this question by comparing a Reality Center, a 3-monitor display system and a single-monitor display system.

They found that a single-screen presentation resulted in similar learning outcomes as the Reality Center. However, the results from their study show that the Reality Center participants felt significantly more immersed when using the Reality Center compared to the single and three screen configurations. Also the Reality Center was found to be more enjoyable and was preferred by the participants. Their study was focused on the effects of immersion on learning and concludes that even though there were no significant differences in what was learnt, a more immersive environment was statistically significantly preferred and thus may encourage students to engage more with the learning material. So while the greater sense of immersion provided by the Reality Center may not assist learning directly, indirectly it can encourage and enhance the learning experience. These recommendations stand in contrast to those of this study, which do not recommend the use of a Reality Center for learning purposes. Therefore, more research in this area is desperately needed to gather more evidence for either finding, especially when looking at the fact that a 3-monitor display system costs only 1% to 5% of a Reality Center. Thus, for further research into the usefulness of virtual environments for fact based teaching purposes a much cheaper and less space consuming display system may be sufficient. Certainly, because of its price and space requirements a Reality Center is not feasible for the public. That said, a Reality Center may produce better results in spatial-navigational learning tasks and for presentation purposes. At the same time, even though participants did not have to learn any particular skills to operate the Reality Center (since they were only watching and listening) it seemed that the exposure to a new and unfamiliar display system may have consumed cognitive resources and therefore, it may be beneficial to familiarise participants with the Reality Center before future experiments. Such a familiarisation could be a one hour gaming session and it would be interesting to investigate if participants who receive a familiarisation session perform better in a subsequent learning task than participants who do not receive a familiarisation session.

Furthermore, the contradictory results between music played during the second half of the VirSchool history lesson in the Reality Center and the 3-monitor display system need to be further explored, maybe even extended beyond the boundaries of the current research scenario. For example, it would be of interest to investigate whether a general musical relaxation treatment of 10-15 minutes prior to experiments has the capacity to return participants from operating in multitasking mode (everyday life) to single tasking mode (learning situations) in which they concentrate on one topic. It would be interesting to see if a similar effect to the one reported by Rauscher *et al.* (1993) (that the 'Mozart Effect' lasted only for 10-15 minutes after exposure to the stimulus) could be observed.

Moreover, the reasons for the statistically significant difference between the Oblivion soundtrack and the 'No Music' condition needs to be investigated further. The main question that arises from this result is why we found a significant result for this particular soundtrack but not for the other soundtracks. In this regard, not only several other musical pieces from different genres but also music could be tested that was specifically composed (i.e. congruent) for a given topic. In this context, it would likely improve the quality of data analysis if participants' memory would be tested after each stimulus ('Music', 'No Music'). This way, it would be avoided that information from the first half and under the influence of one stimulus would be covered by information and the stimulus in the second half. Still, the order of the stimuli would have to be reversed for a second group of participants to ensure that the differences of the means are not due to the different information presented in both halves. Ideally, one would create three parts of an experiment and sort them in an A>B>A and B>A>B order to investigate for carry-over effects (Kuehl, 2000, p. 520), however, this only works if the information is non-chronological, which is not easily possible for a historical narration but would work for other experiments.

Of course, other presentation methods, like for example presenting the same historical facts about the Macquarie Lighthouse in written form on paper or reading out the same story in an audio-only narrative without visuals, would produce additional knowledge about the effectiveness of virtual environments in comparison to more traditional teaching methods. In this context, it would also make sense to further investigate the role that music, immersion and feeling of presence play in supporting learners in their learning activities. Additionally, one could avoid the between subjects design of Experiment 1 and expose all participants to the five different combinations of tempo (slow, fast), pitch (low, high) and 'No Music' to get more conclusive results on the effects of tempo and pitch on memory. However, this solution would be very expensive and time consuming and as an alternative one could simply increase the sample size and select participants randomly.

Also, it would add to the knowledge in the area of the effect of music on learning in virtual environments to find out which effect different musical pieces from various genres and their associated tempo have on brainwave frequency and whether brainwave frequency can be manipulated by music and which particular brainwave frequency is most beneficial for learning. One study has investigated such connections (Rosenfeld *et al.*, 1997), however, the unit utilised in these experiments mostly focuses on the use of light pulses and audible frequencies at the desired alpha brainwave frequency (8-12 Hz). This frequency is inaudible to the human ear (Machrone, 2004) and can thus not be called 'Music', however, the effect of these frequencies on learning would be of interest as a follow-up experiment to the present study. More research in this area is needed and such investigations could create widely different results with different target populations.

Further to the investigations whether music can be used as a tool to block other distractions and thus improve concentration on a particular topic (which in turn may facilitate learning) it would be intriguing to investigate which effect a general relaxation exercise, with music or meditation/breathing exercises as a primer, would have on participants' learning performance in computer-animated teaching lessons which follow the relaxation exercise. Also, participants' lifestyle could have an effect on their learning performance. Asking them whether they lead a busy or rather calm lifestyle and how they feel in terms of stress on the day of the experiment could give further insights into which group of people react best to a musically enhanced virtual teaching environment. Also, a combination of collecting data by means of questionnaires and selected interviews of representative experiment participants could reveal insights into aspects not covered in the questionnaires while at the same time retaining the quantitative analyses possible by the data collected in the questionnaires. In this regard it would also be of importance to add a measure of the level of immersion and presence in the virtual environment to the research method in order to investigate if a higher level of immersion creates a higher level of feeling of presence and whether a heightened level of presence results in a better learning performance by participants.

One point that requires particular attention is the reported average difference of the number of correctly remembered facts from the VirSchool history lesson between genders. As was said before, the lower performance of the female participants could be due to the high percentage of non-native English speakers in that particular experimental group. In this regard, further investigations are desperately needed to clarify the connection between memory and the instruction language being the first or second language of participants.

Furthermore, it would be compelling to create a truly experiential (i.e. freely explorable and interactive) virtual environment with a quest system similar to a commercial video game. Game design would revolve around a system including levels, which means that a new historical or scientific topic can be explored as soon as the quests and puzzles from one level have been solved. Thus, an incentive would be given to 'master' one VirSchool lesson and progress to the next topic. In such an environment it would also be interesting to observe how multiple users interact in a common virtual learning environment and how the presence of other learners influences learning outcomes of individuals.

With these results and suggestions in mind and looking at the high likelihood of virtual environments becoming more prominent in the near future with increased quality and performance, it was the motivation of this study to contribute to the creation of effective learning environments in the 21st century. In this regard, it was the intention of this study to evaluate the role that music plays in such learning environments. Conceivably, the use of music may not only act as a subtle attractor and motivator for students to engage with the learning matter, but may also facilitate learning itself. Hopefully, this thesis contributes to the knowledge in this area and motivates future investigations of the effect of music on learning in virtual environments.

APPENDIX

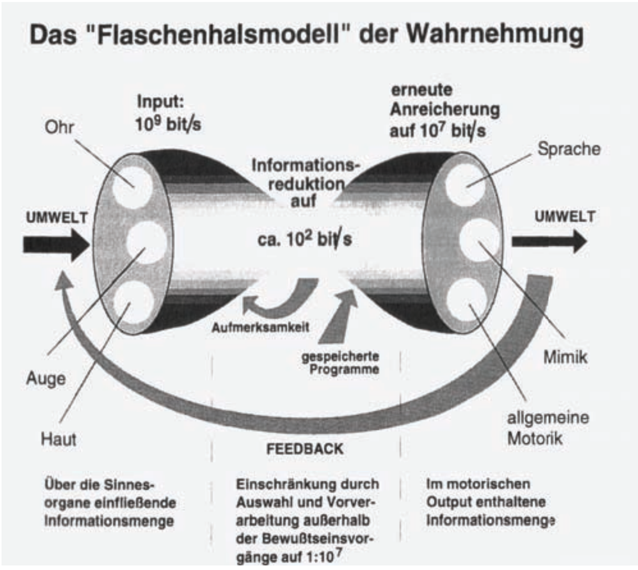
A

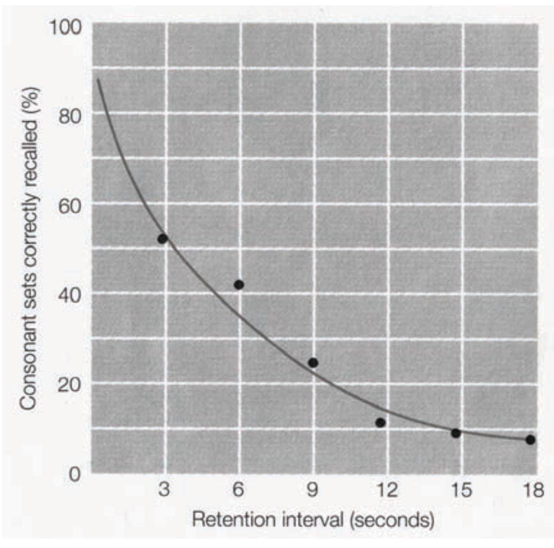
Extensive research has been conducted on memory and the following information is mostly based on the accumulated knowledge compiled and published by Weiten (1992) and Vester (1975). Nevertheless, we will look at other findings and point out the different views where appropriate.

5.3.1.1 Storage

The most popular approach to look at the storage of information is to categorise human memory into short-term and long-term memory. Our senses are therefore the point of contact for any information coming from the external world into our system. **Sensory Memory** plays an important part in this process as it is the physical memory of our senses (sight, hearing, touch, taste and smell) that preserves the incoming information in its original form for further processing. Sensory Memory keeps information in store only for a small amount of time. For our eyes this would be approximately 0.25 seconds (Weiten, 1992) and one can easily observe this effect when looking at fire twirlers at night - the circle that their burning sticks or cups produce is due to the latency of the processing of the information by our eyes. On the aural side Dix *et al.* (Dix *et al.*, 1998, p. 27) explain sensory memory at hand of an example of a friend approaching and asking us a question while we are highly concentrated on something else. Although, we might ask the friend to repeat his question, we are very likely to know roughly what he or she is going to tell us. Our sensory memory preserves the information for a certain time and then hands it over to our Short-Term Memory.

According to Vester we have to filter the information from 10^9 different stimuli per second down to approximately 100 bits of information per second. Our brain performs this task naturally as a sort of filter to prevent us from an information overload.


Das "Flaschenhalsmodell" der Wahrnehmung
Input:
10^9 bit/s
Ohr
erneute
Anreicherung
auf 10^7 bit/s
Sprache
Informations-
reduktion
auf
ca. 10^2 bit/s
UMWELT
UMWELT
Aufmerksamkeit
gespeicherte
Programme
Auge
Mimik
Haut
FEEDBACK
allgemeine
Motorik
Über die Sinnes-
organe einfließende
Informationsmenge
Einschränkung durch
Auswahl und Vorver-
arbeitung außerhalb
der Bewußtseinsvor-
gänge auf 1:10^7
Im motorischen
Output enthaltene
Informationsmenge


100
80
60
40
20
0
Consonant sets correctly recalled (%)
3
6
9
12
15
18
Retention interval (seconds)

Vester also says that it is vital during this time to link new information to a previous experience or some piece of information that we have already stored, basically something we can relate the new information to. Vester says that the more senses we involve in offering new information to the human brain, the more opportunities it has to link the new information to information that is already stored. By doing this we keep the information in our STM and prevent it from getting dropped.

Semantic Networks are probably described earlier by Aristotle in his study of free association where he introduces three principles which describe "how one thought leads to another"(Mazur, 1998). The three principles outlined in Mazur (1998) are **contiguity**, **similarity** and **contrast** and basically describe the same methods as explained above. *Contiguity* means that if we think of one thing that is spatially or timely close to a second one, we are very likely to remember the second one. Table and chair are an example for such contiguity. *Similarity* in the context of fruit would for example be that the colour red reminds us of apples and oranges. *Contrast* means that if we think of one thing then we can easily remember the opposite.

As we said before, this is the most commonly agreed model of the encoding process of information into human memory. Franz Decker extends this model by adding another step to Short-Term/Long-Term categorisation. He calls, what is otherwise considered to be Short-Term Memory, "**Ultra-Short-Term Memory**", meaning the time that the brain holds new information at the very first instance. This Ultra-Short-Term Memory is the 20 second maximum that was described at hand of Figure 53 earlier. Vesters' difference to the common model comes after these initial 20 seconds. In his model Short-Term Memory is a period of approximately 20 **minutes** where the brain produces RNA (Ribonucleic Acid) templates out of our own DNA (Deoxyribonucleic Acid). These RNA templates then travel through ribosomes and are transformed into long protein molecules that fold up to a ball and are deposited into a cell. This process takes about 20 minutes. The RNA template dissolves afterwards but the information is stored permanently.

Vester undermines his model with the effect that we all know from an extraordinary event like a car accident. Very often people find themselves remembering things that happened 20 minutes before the accident but not the accident itself. Vester claims that this might be due to the fact that the production of the protein molecules in the ribosomes (which takes about 20 minutes) has been interrupted and thus the information is lost.

Vester also developed a comprehensive model of memory and how things are interlinked with each other. The full model can be found in his book (Vester, 1975). For now we want to highlight one particular point where Vester says that humans have a general tendency to be defensive towards new things. Fortunately, he says, nature has equipped us with a character trait to overcome this attitude - curiosity. It is this curiosity that enables us to actually pay attention to something new and develop the motivation that is necessary to keep something in our (Ultra-) Short-Term Memory long enough so that it can be processed further into our Long-Term Memory. Having looked at how information is encoded and how it is stored in our brain we now want to explain how this information is retrieved from memory.

5.3.1.2 Retrieval

One method that we want to look at is the **Cued Recall**. As we learned before, newly imprinted information is connected to older information. This information can be accessed by cues that lead us to the information. Schacter gives an example (Schacter, 1996) of a wedding where a new person, who's name is Bill, stands near the readers aunt Helen. We probably all know the phenomenon that if we are asked for Bill's name later, we might not be able to recall his name without further help. However, if we are given the cue that he was standing next to our aunt Helen we are more likely to recall his name. Another example would be the situation described by Hunt and Ellis.

> *"For example, what were you doing at 10:00 AM on November 26, 1997? At first glance, this may appear to be a difficult question, but we shall give you a cue and let you think about it. November 26 was the Wednesday before Thanksgiving Day. Now, can you answer the question? Regardless of the situation, most people can provide an answer when cues are given. The fact that the question could be answered indicates that information was available, but most people require the clues to render the information accessible". (Hunt et al., 1999)*

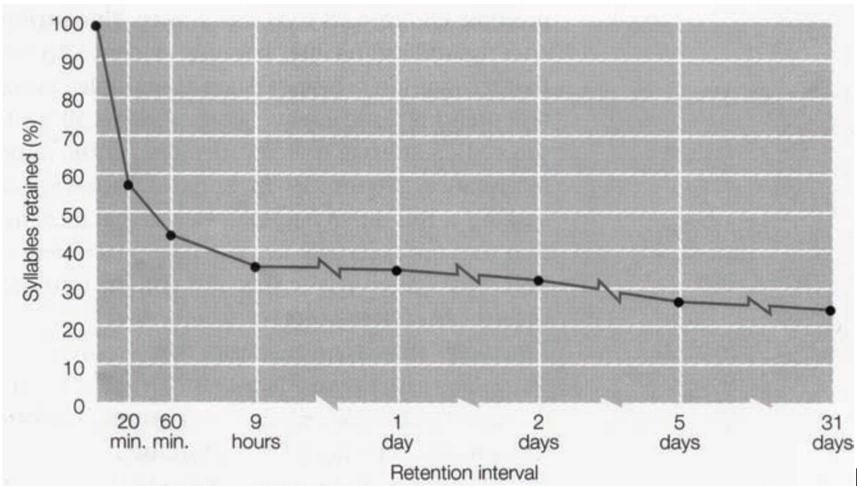
Both of these examples show that we access information in our brains from one node to the next and continue until we have found the desired information. Daniel Schacter even suggests, "encoding and remembering are virtually inseparable."

Furthermore Schacter states that memory is a very personal thing and that

> *"we remember only what we have encoded, and what we encode depends on who we are - our past experiences, knowledge and needs all have a powerful influence on what we retain. This is one reason why two different people can sometimes have radically divergent recollections of the same event" (Schacter, 1996).*

Having looked at encoding, storage and retrieval of information we now want to look at one other process related to memory – forgetting.

5.3.1.3 Forgetting



remember and can not? Weiten mentions four major possible explanations for this forgetting. He also describes in detail the tests that lead to the findings and for those readers who are interested in the actual tests we suggest taking a closer look at Weiten's book " Psychology: Themes and Variations ". For now we want to focus on the four theories, of which the first is called **Ineffective Encoding** which means that the information was not encoded thoroughly into LTM when it was supposed to be learned in the first place. Weiten says that forgetting is "usually due to lack of attention". The second theory why forgetting happens is **Decay** and the underlying physiological mechanisms that play a role in it. However, "Researchers have *not* been able to demonstrate that decay causes LTM forgetting" (Weiten, 1992). Since physiological decay is not proven until today, one of the most likely reasons for forgetting is **Interference**. This theory says that some information cannot be recalled because it is covered by other, similar information. The fourth theory why humans forget things is called **Retrieval Failure** and it describes a problem associated with the cued recall discussed earlier in this chapter. What it means is that a poor or wrong association to the new information has been established during encoding and thus our cue does not lead us to the desired information. These are the four theories why forgetting happens in humans and for the purpose of our research this knowledge seems to be adequate. For further information Weiten's book can be highly recommended.

APPENDIX B

DSM-IV-TR list of criteria for diagnosis of ADHD

People are diagnosed with ADHD according to the following criteria:

A. Either (1) or (2):

(1) six (or more) of the following symptoms of inattention have persisted for at least 6 months to a degree that is maladaptive and inconsistent with developmental level:

a) Inattention

b) often fails to give close attention to details or makes careless mistakes in schoolwork, work, or other activities

c) often has difficulty sustaining attention in tasks or play activities

d) often does not seem to listen when spoken to directly

e) often does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace (not due to oppositional behaviour or failure to understand instructions)

f) often has difficulty organizing tasks and activities

g) often avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort (such as schoolwork or homework)

h) often loses things necessary for tasks or activities (e.g. toys, school assignments, pencils, books, or tools)

i) is often easily distracted by extraneous stimuli

j) is often forgetful in daily activities

(2) six (or more) of the following symptoms of hyperactivity-impulsivity have persisted for at least 6 months to a degree that is maladaptive and inconsistent with developmental level:

a) Hyperactivity

b) often fidgets with hands or feet or squirms in seat

c) often leaves seat in classroom or in other situations in which remaining seated is expected

d) often runs about or climbs excessively in situations where it is inappropriate (in adolescents or adults, may be limited to subjective feelings of restlessness)

e) often has difficulty playing or engaging in leisure activities quietly

f) is often "on the go" or often acts as if "driven by a motor"

g) often talks excessively

h) Impulsivity

i) often blurts out answers before questions have been completed

j) often has difficulty awaiting turn

k) often interrupts or intrudes on others (e.g. butts into conversations or games)

B. Some hyperactive-impulsive or inattentive symptoms that cause impairment were present before age 7 years.

C. Some impairment from the symptoms is present in two or more settings (e.g. at school [or work] and at home).

D. There must be clear evidence of clinically significant impairment in social, academic, or occupational functioning.

E. The symptoms do not occur exclusively during the course of a Pervasive Developmental Disorder, Schizophrenia, or other Psychotic Disorder and are not better accounted for by another mental disorder (e.g. Mood Disorder, Anxiety Disorder, Dissociative Disorder or a Personality Disorder)

The definition given above helps doctors and therapists to assess whether a patient can be diagnosed as having ADHD and once the diagnosis is established there are several approaches to aid patients, especially children, with ADHD.

APPENDIX C

Name of Project: **VirSchool – An immersive environment for learning purposes**

You are invited to participate in a research project about the use of virtual environments for learning purposes and as a teaching tool.

The study titled "VirSchool – An immersive environment for improved learning" will involve an audio-visual presentation of a historical 3d course. After the presentation we will ask you to fill out a questionnaire. The trial will take up to forty-five (45) minutes and you will be paid $10 for your involvement.

The study is being conducted to meet the requirements for the PhD degree of Eric Fassbender, Dipl.Inf. (FH) (02 9850 6343), under the supervision and help of, Assoc. Prof. Debbie Richards, Prof. William Forde Thompson, Dr Manolya Kavakli and John Porte in the Computing and Psychology Department. The study is confidential and no personal details are gathered in the study. We will send you a copy of the confidential results within 6 - 12 months if you wish to leave your email address after the experiment. Participation in this study is purely voluntary and you can stop the study at any time without giving the reasons.

Please note that if you suffer from any health problems (for example, inner ear problems), you might be affected by potential discomfort such as nausea and disorientation from participating in virtual reality experiments. If you feel nauseous or feel another discomfort during the experiment, please signal the researchers and stop the experiment immediately. If you think you might have a condition that might be affected by these experiments, please consult a doctor before consenting to participate or resign from participation.

Please **do not** include your name on the **questionnaires**. No personal details are gathered in this study.

I, ____________ have read *(or, where appropriate, have had read to me)* and understand the information above and any questions I have asked have been answered to my satisfaction. I agree to participate in this research, knowing that I can withdraw from further participation in the research at any time without consequence. I have been given a copy of this signed form to keep.

Participant's Name: ________________________
(block letters)

Participant's Signature: ______________________________Date: ____________

Investigator's Name: ________________________
(block letters)

Investigator's Signature: ____________________________Date: ____________

The ethical aspects of this study have been approved by the Macquarie University Ethics Review Committee (Human Research). If you have any complaints or reservations about any ethical aspect of your participation in this research, you may contact the Committee through the Research Ethics Officer (telephone [02] 9850 7854, fax [02] 9850 8799, email: ethics@mq.edu.au). Any complaint you make will be treated in confidence and investigated, and you will be informed of the outcome.

This study is funded by iMURS (international Macquarie University Scholarship).

PARTICIPANT'S COPY

Name of Project: **VirSchool – An immersive environment for learning purposes**

You are invited to participate in a research project about the use of virtual environments for learning purposes and as a teaching tool.

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Participant's Name: ________________________
(block letters)

Participant's Signature: ____________________________Date: ____________

Investigator's Name: ________________________
(block letters)

Investigator's Signature: ____________________________Date: ____________

The ethical aspects of this study have been approved by the Macquarie University Ethics Review Committee (Human Research). If you have any complaints or reservations about any ethical aspect of your participation in this research, you may contact the Committee through the Research Ethics Officer (telephone [02] 9850 7854, fax [02] 9850 8799, email: ethics@mq.edu.au). Any complaint you make will be treated in confidence and investigated, and you will be informed of the outcome.

This study is funded by iMURS (international Macquarie University Scholarship).

RESEARCHER'S COPY

Questionnaire Experiment 1

☐ First ☐ Second ☐ Third or other

Office Use (to be filled out by researchers)

Participant Number: _____

Condition Number: _____

Part B

Please answer the following questions. Note that for the **Multiple Choice** questions, there is only **ONE** correct answer. Please answer each question only once and do not go back and correct any answer at a later stage. If you do not know the answer to a question simply tick none of the boxes. Remember this is not a test and your honest answer will help more than guessing.

B1 What was the name of the captain of the Endeavour who proclaimed Australia a British colony?

☐	Captain Arthur Phillip
☐	Captain James Cook
☐	Captain Jack Sparrow
☐	Captain William Blight

B2 Before arriving in Australia, the crew on board the Endeavour observed the transit of a planet. What is the name of the planet?

☐	Venus
☐	Mars
☐	Mercury
☐	Saturn

B3 Where did the Endeavour first land when it arrived in Australia?

☐	Fannie Bay
☐	Byron Bay
☐	Botany Bay
☐	Banks Bay

B4 In which year did the First Fleet arrive in Australia?

☐	1770
☐	1880
☐	1788
☐	1492

B5 What was the name of the commander of the First Fleet?

☐	Captain Arthur Phillip
☐	Captain James Cook
☐	Captain Jack Sparrow
☐	Captain William Blight

B6 Where was the first settlement established? Give the name of the port.

☐	Port Darwin
☐	Port Botany
☐	Port Patterson
☐	Port Jackson

B7 What is the more common name for that port?

☐	Sydney Harbour
☐	Coffs Harbour
☐	Port Stephens
☐	Port Botany

B8 When was the first flagstaff erected?

☐	1783
☐	1717
☐	1813
☐	1790

B9 What was the purpose of the flagstaff?

A ☐	To signal the arrival of a long expected ship to the settlers
B ☐	To signal to the expected ship where the settlement was located
C ☐	To increase the visibility of the landmark
D ☐	A and B
E ☐	B and C

B11 How many months after the arrival of the supply ship was the stone column erected near the flagstaff?

☐	2
☐	4
☐	6
☐	8
☐	10
☐	12

B12 Why was the stone column built?

A ☐	To signal the arrival of a long expected ship to the settlers
B ☐	To signal to the expected ship where the settlement was located
C ☐	To increase the visibility of the landmark
D ☐	A and B
E ☐	B and C

B13 How many people were stationed at the flagstaff and column at this time (i.e. after the construction of the column)

☐	3
☐	5
☐	7
☐	9
☐	11
☐	13

B14 What did the soldiers have at the flagstaff and column?

A ☐	Some huts
B ☐	A fishing boat
C ☐	A garden
D ☐	A and B
E ☐	B and C
F ☐	All of the above

B15 The height of the first flagstaff was found to be too short and a second flagstaff was erected. How tall was this second flagstaff?

☐	7 m
☐	9 m
☐	11 m
☐	13 m
☐	15 m
☐	17 m

B16 A second event happened in the same year that the second flagstaff was erected. What was it?

A ☐	The stone column was destroyed
B ☐	A beacon light was installed
C ☐	The flagstaff collapsed
D ☐	A and C
E ☐	A, B and C

B17 When was the first Macquarie Lighthouse built?

☐	1783
☐	1770
☐	1818
☐	1790
☐	1820

B18 What was the name of the architect who built the first Macquarie Lighthouse?

☐	William Wright
☐	Francis Wright
☐	William Greenway
☐	Francis Greenway

B19 Where is the Macquarie Lighthouse situated according to what you learned in this course?

☐	The south peninsula of the harbour
☐	The north peninsula of the harbour
☐	Inside the harbour near the settlement

B20 How tall was the first Macquarie Lighthouse?

☐	17.80 m
☐	18.90 m
☐	19.80 m
☐	20.90 m
☐	21.80 m
☐	22.90 m

B 21 What is the name of the first lighthouse keeper?

☐	Robert Watson
☐	Thomas Watson
☐	Robert Jackson
☐	Thomas Jackson

B22 How many months after he started his duty did the first lighthouse keeper die?

☐	2
☐	4
☐	6
☐	8
☐	10
☐	12

B23 The first lighthouse started to fall apart only 5 years after its construction. What were the reasons?

A ☐	The sandstone was of poor quality
B ☐	The mortar was of poor quality
C ☐	Problems with the foundation
D ☐	A and B
E ☐	B and C
F ☐	A, B and C

B24 How many people died in the accident of the Dunbar?

☐	22
☐	122
☐	11
☐	111

B25 What was the name of the only survivor of this catastrophe?

☐	William Johnson
☐	James Johnson
☐	William Thompson
☐	James Thompson

B26 When was the construction of the second Macquarie Lighthouse finished?

☐	1783
☐	1835
☐	1850
☐	1890
☐	1883

B27 What was the name of the architect of this second lighthouse?

☐	George Barnet
☐	James Barnet
☐	George Bennett
☐	James Bennett

B28 The innovative Fresnel lens system of the new lighthouse was visible

☐	25 nautical miles
☐	27 nautical miles
☐	29 nautical miles
☐	31 nautical miles
☐	33 nautical miles

B29 At the beginning of the new century, it was claimed that the gas-generated electricity was too expensive to operate the lighthouse. As a result, the lighting apparatus was replaced with a kerosene system, which was less powerful. For this reason the system was reconverted to electricity in the year

☐	1927
☐	1929
☐	1931
☐	1933
☐	1935

B30 What led to the demanning of the lighthouse in1989?

☐	The construction of a new lighthouse in a better position
☐	Financial restrictions of the Sydney council
☐	The rapid development in other navigational systems
☐	All of the above
☐	None of the above

Part C

C1 How hard did you find it to concentrate?

☐	☐	☐	☐	☐
not hard at all		neutral		very hard

C2 How well were you concentrating?

☐	☐	☐	☐	☐
not at all		neutral		completely

C3 How self-conscious were you?

☐	☐	☐	☐	☐
not at all		neutral		completely

C4 Please rate the level of difficulty of the virtual course:

☐	☐	☐	☐	☐
low		medium		high

C5 Did you wish you had been doing something else?

☐	☐	☐	☐	☐
not at all		neutral		completely

C6 Do you think you **succeed**ed in what you were doing?

☐	☐	☐	☐	☐
not at all		neutral		completely

C7 Did you feel nauseous or uncomfortable in the virtual environment?

☐	☐	☐	☐	☐
not at all		neutral		completely

C8 Do you think that this virtual environment was a useful learning tool?

☐	☐	☐	☐	☐
not at all		neutral		completely

C9 What are the reasons for your opinion?

____

____

C10 Which part of the learning environment did you find most helpful? Please rank from 1 – 4 with 1 being the most helpful and 4 being the least helpful.

___ Aural dialog
___ Written information
___ Visual presentation
___ Musical background/sound conditions

C11 Did you like the music you were listening to?

☐	☐	☐	☐	☐
not at all		neutral		completely

C12 What are the reasons for your opinion?

____

____

____

C13 Did you recognise the music that was playing during the experiment?

☐	☐
Yes	No

C14 If yes, what music do you think it was?

____

C15 Do you think that the music distracted you from the topic matter?

☐	☐	☐	☐	☐
not at all		neutral		completely

C16 What are the reasons for your opinion?

____

C17 Do you think that the music assisted you to concentrate on the topic matter?

☐	☐	☐	☐	☐
not at all		neutral		completely

C18 What are the reasons for your opinion?

____

C19 Do you know any of the researchers conducting the experiment?

☐	☐
Yes	No

C20 If yes, who?

____

C21 Are you generally interested in History/Australian History?

☐	☐	☐	☐	☐
not at all		neutral		completely

C22 Did you know any of the facts that you learned in the virtual course before you participated in this experiment?

☐	☐
Yes	No

C23 If yes, please give the number of the question.

<u>Note:</u> You are allowed to go back through the questionnaire to get the number, but please do not change any of your answers.

____

____

C24 How much did you loose track of time?

☐	☐	☐	☐	☐
not at all		neutral		completely

C25 How much did you forget about yourself (i.e. forgot about problems with Uni, boy-/girlfriend, family etc.)

☐	☐	☐	☐	☐
not at all		neutral		completely

C26 How much were you aware of the real world around you? Please answer the three subcategories

C26a Was there any aural distraction, i.e. external sounds?

☐	☐	☐	☐	☐
not at all		neutral		completely

C26b Was there any visual distraction?

☐	☐	☐	☐	☐
not at all		neutral		completely

C26c Was there any personal distraction, i.e. other peoples?

☐	☐	☐	☐	☐
not at all		neutral		completely

C27 How long do you think the video-presentation ran for?

____

Part D

Please answer the following questions.

D1 How many years have you been playing computer/console games?

☐	☐	☐	☐	☐
0-1	2-4	5-7	8-10	More than 10

D2 How many hours do you spend playing computer/console games every week?

☐	☐	☐	☐	☐
0-5	6-10	11-20	21-30	More than 30

D3 How many years have you been playing a musical instrument?

☐	☐	☐	☐	☐
0-1	2-4	5-7	8-10	More than 10

D4 How many years of formal training did you have in learning how to play a musical instrument?

☐	☐	☐	☐	☐
0-1	2-4	5-7	8-10	More than 10

D5 Are you currently actively engaged in music, i.e. playing in a band, composing, etc.?

☐	☐
Yes	No

D6 Do you have any other comments you would like us to know?

____

____

____

Questionnaire Experiment 2

This questionnaire includes some "Likert scale" questions in Part A, C and D alongside some multiple choice questions in Part B. Please answer the Likert scale questions according to the following example.

<u>Example:</u> How compelling do you find the colour purple?

☐	☐	☐	☐	☐
not compelling at all		somewhat compelling		very compelling

If you really dislike the colour purple and would never, for example, wear a pair of socks in that colour please check the box above "not compelling at all". If you like the colour purple and you buy purple socks regularly and wear them as often as possible please check the box above "very compelling". If you have a pair of purple socks in your drawer and you don't think about whether you want to wear them on a particular day please check the box above "somewhat compelling".
The checkboxes between the extreme ratings and the middle rating allow for variations of like or dislike of the colour purple. So if you don't particularly like the colour purple but you would wear socks that were given to you as a gift when you are visiting the person that gave you the socks please check the box between "not compelling at all" and "somewhat compelling". If on the other hand you would buy the socks yourself but would not necessarily wear them every week please check the box between "somewhat compelling" and "very compelling".

Part A

A1 Your Age: ___

A2 Your Gender: M ☐ F ☐

A3 Is English your first, second, third or other language?

☐	☐	☐
First	Second	Third or other

A4 If English is not your first language, what is your first language and in which country did you spend most of your time before coming to Australia?

____

____

A5 Are you generally interested in History/Australian History?

☐	☐	☐	☐	☐
not interested at all		somewhat interested		very interested

A6 How often do external sounds or movements distract you from your task (e.g. reading a chapter in a book) when you are studying?

☐	☐	☐	☐	☐
never		sometimes		very often

A7 How well are you usually able to concentrate on a task when you are studying?

☐	☐	☐	☐	☐
not able to concentrate at all		somewhat able to concentrate		very well able to concentrate

Office Use (to be filled out by researchers)

Participant Number: _____

Condition Number: _____

Part B

Please answer the following questions. Note that for the **Multiple Choice** questions, there is only **ONE** correct answer. Please answer each question only once and do not go back and correct any answer at a later stage. If you do not know the answer to a question simply do not tick any of the boxes. Remember this is not a test and your honest answer will help more than guessing.

B1 In which year did the First Fleet arrive in Australia?

☐	1770
☐	1880
☐	1788
☐	1492

B2 What was the name of the commander of the First Fleet?

☐	Captain Arthur Phillip
☐	Captain James Cook
☐	Captain Jack Sparrow
☐	Captain William Blight

B3 Where was the first settlement established? Give the name of the port.

☐	Port Darwin
☐	Port Botany
☐	Port Patterson
☐	Port Jackson

B4 What is the more common name for that port?

☐	Sydney Harbour
☐	Coffs Harbour
☐	Port Stephens
☐	Port Botany

B5 When was the first flagstaff erected?

☐	1783
☐	1717
☐	1813
☐	1790

B6 What was the purpose of the flagstaff?

A ☐	To signal the arrival of a long expected ship to the settlers
B ☐	To signal to the expected ship where the settlement was located
C ☐	To increase the visibility of the landmark
D ☐	A and B

B7 How many months after the arrival of the supply ship was the stone column erected near the flagstaff?

☐	2
☐	4
☐	6
☐	8

B8 Why was the stone column built?

A ☐	To signal the arrival of a long expected ship to the settlers
B ☐	To signal to the expected ship where the settlement was located
C ☐	To increase the visibility of the landmark
D ☐	B and C

B9 How many people were stationed at the flagstaff and column at this time (i.e. after the construction of the column)

☐	7
☐	9
☐	11
☐	13

B10 What did the soldiers have at the flagstaff and column?

A ☐	Some huts
B ☐	A fishing boat
C ☐	A garden
D ☐	All of the above

B11 The height of the first flagstaff was found to be too short and a second flagstaff was erected. How tall was this second flagstaff?

☐	7 m
☐	9 m
☐	11 m
☐	13 m

B12 A second event happened in the same year that the second flagstaff was erected. What was it?

A ☐	The stone column was destroyed
B ☐	A beacon light was installed
C ☐	The flagstaff collapsed
D ☐	A and C

B13 When was the first Macquarie Lighthouse built?

☐	1770
☐	1818
☐	1790
☐	1820

B14 What was the name of the architect who built the first Macquarie Lighthouse?

☐	William Wright
☐	Francis Wright
☐	William Greenway
☐	Francis Greenway

B15 Where is the Macquarie Lighthouse situated according to what you learned in this course?

☐	The south peninsula of the harbour
☐	The north peninsula of the harbour
☐	Inside the harbour near the settlement
☐	Inside the harbour about 2 km away from the settlement

B16 How tall was the first Macquarie Lighthouse?

☐	17.80 m
☐	18.90 m
☐	19.80 m
☐	20.90 m

B 17 What was the name of the first lighthouse keeper?

☐	Robert Watson
☐	Thomas Watson
☐	Robert Jackson
☐	Thomas Jackson

B18 How many months after he started his duty did the first lighthouse keeper die?

☐	6
☐	8
☐	10
☐	12

9 The first lighthouse started to fall apart only 5 years after its construction. What were the reasons?

A ☐	The sandstone was of poor quality
B ☐	The mortar was of poor quality
C ☐	Problems with the foundation
D ☐	A and B

B20 How many people died in the accident of the Dunbar?

☐	22
☐	122
☐	11
☐	111

B21 What was the name of the only survivor of this catastrophe?

☐	William Johnson
☐	James Johnson
☐	William Thompson
☐	James Thompson

B22 What was the name of the other ship that sunk in the same year?

☐	Endeavour
☐	Bounty
☐	Catherine Adamson
☐	Queen Elizabeth

B23 When was the construction of the second Macquarie Lighthouse finished?

☐	1835
☐	1850
☐	1890
☐	1883

B24 What was the name of the architect of this second lighthouse?

☐	George Barnet
☐	James Barnet
☐	George Bennett
☐	James Bennett

B25 How far away was the second lighthouse built from the first lighthouse?

☐	2 metres
☐	2 kilometres
☐	3.5 metres
☐	3.5 kilometres

B26 What was the name of the innovative lens system that was used in the new lighthouse?

☐	Fresnel lens system
☐	Plano-concave lens system
☐	Telecentric lens system
☐	Afocal relay lens sytem

B27 The innovative lens system of the new lighthouse was visible

☐	25 nautical miles
☐	27 nautical miles
☐	29 nautical miles
☐	31 nautical miles

B28 The electrical power for the new lighting apparatus was produced by two generators. What was the name of these generators?

☐	Souter Point Holmes Machines alternators
☐	Penmarc'h Two-phase Labour alternators
☐	De Meritens Magnetos alternators
☐	Navesink Dynamo alternators

B29 At the beginning of the new century, it was claimed that the gas-generated electricity was too expensive to operate the lighthouse. As a result, the lighting apparatus was replaced with a kerosene system, which was less powerful. For this reason the system was reconverted to electricity in the year

☐	1929
☐	1931
☐	1933
☐	1935

B30 What led to the demanning of the lighthouse in1989?

☐	The construction of a new lighthouse in a better position
☐	Financial restrictions of the Sydney council
☐	The rapid development in other navigational systems
☐	All of the above

Part C

C1 How well were you able to concentrate on the subject matter of the computer-animated history lesson?

☐	☐	☐	☐	☐
not able to concentrate at all		somewhat able to concentrate		very well able to concentrate

C2 Overall, how hard was it to remember information contained in the computer-animated history lesson?

☐	☐	☐	☐	☐
not hard at all		moderately hard		very hard

C3 How often did you wish you had been doing something else?

☐	☐	☐	☐	☐
never		sometimes		very often

C4 How well do you think you succeeded in remembering information from the computer-animated history lesson?

☐	☐	☐	☐	☐
did not succeed at all		somewhat succeeded		completely succeeded

C5 How often did you loose track of time while watching and listening to the computer-animated history lesson?

☐	☐	☐	☐	☐
never		sometimes		very often

C6 How much did you forget about yourself (i.e. forgot about problems with Uni, boy-/girlfriend, family etc.) while watching and listening to the computer-animated history lesson?

☐	☐	☐	☐	☐
did not forget about myself at all		somewhat forgot about myself		completely forgot about myself

C7 How often did you feel nauseous or uncomfortable in the virtual environment?

☐	☐	☐	☐	☐
never		sometimes		very often

C8 Do you think that this virtual environment was a useful learning tool?

☐	☐
Yes	No

What are the reasons for your opinion? ______________________________

____

____

C9 Which part of the computer-animated history lesson was most useful for your learning of the subject matter?

☐	Visuals
☐	Audio-Narration
☐	Background Music
☐	Written text

☐ Other ______________________________

C10 Do you usually listen to music while you are studying?

☐	☐
Yes	No

- If yes, continue with question C11
- If no, go to question C14

C11 Which of the two categories best describes the music that you mostly listen to while studying?

☐	Instrumental/without lyrics
☐	Vocalised/with lyrics

C12 Which type of music do you mainly listen to when you are studying? (Multiple answers are possible)

☐	Rock/Pop
☐	Heavy Metal/Hard Rock
☐	Folk/Country
☐	Carnatic
☐	Celtic
☐	Reggae
☐	Classical
☐	Opera
☐	Acoustical Guitar
☐	Electronic, Trance, Dance etc.
☐	Electronic Ambient
☐	New Age
☐	Downtempo
☐	Chillout/Lounge
☐	Emo
☐	House
☐	Jazz
☐	Ragga
☐	World, Traditional
☐	Hip Hop
☐	Rap
☐	Nature Sounds
☐	Meditational

☐ Other (Multiple answers possible) ______________________________

C13 In terms of tempo would you say that the music you listen to while studying is playing at a fast, medium or slow tempo (experienced subjectively)?

☐	Fast Tempo
☐	Medium Tempo
☐	Slow Tempo

C14 Did you notice any background music during the computer-animated history lesson?

☐	☐
Yes	No

- If yes, continue with question C15
- If no, go to question C21

C15 The computer-animated history lesson was split into two parts. You watched one half accompanied by background music and the other half without any background music. In which half of the computer-animated history lesson did you notice the music?

☐	☐
First half	Second half

C16 Which part of the computer-animated history lesson did you enjoy more?

☐	☐
Part **with** background music	Part **without** background music

C17 How much did you like the music that was playing in the background of the computer-animated history lesson that you just watched?

☐	☐	☐	☐	☐
I did not like the music at all		I somewhat liked the music		I liked the music very much

C18 How appropriate do you think the music was in the context of the history lesson about the Macquarie Lighthouse?

☐	☐	☐	☐	☐
not appropriate at all		somewhat appropriate		very appropriate

C19 Do you think that the music distracted you from concentrating on the topic matter?

☐	☐	☐	☐	☐
music did not distract me at all		music somewhat distracted me		music distracted me very much

C20 Do you think that the music assisted you to concentrate on the topic matter?

☐	☐	☐	☐	☐
music did not assist at all		music somewhat assisted		music assisted very much

C21 Did you know any of the facts that you learned in the virtual course before you participated in this experiment?

☐	☐
Yes	No

- If yes, answer on the lines provided below

Note: At this point please go back through the questionnaire to get the correct numbers (B1 – B30) of the questions that you knew before the experiment. However, please do not change any of your original answers to those questions.

____

____

- If no, go to Part D

Part D

Please answer the following questions.

D1 How many years have you been playing computer/console games?

☐	☐	☐	☐	☐
0-1	2-4	5-7	8-10	More than 10

D2 How many hours do you spend playing computer/console games every week?

☐	☐	☐	☐	☐
0-5	6-10	11-20	21-30	More than 30

D3 How many years have you been playing a musical instrument?

☐	☐	☐	☐	☐
0-1	2-4	5-7	8-10	More than 10

D4 How many years of formal training did you have in learning how to play a musical instrument?

☐	☐	☐	☐	☐
0-1	2-4	5-7	8-10	More than 10

D5 Are you currently actively engaged in music, i.e. playing in a band, composing, etc.?

☐	☐
Yes	No

D6 In which category do you get most of your marks?

☐	HD (High Distinction)
☐	D (Distinction)
☐	Cr (Credit)
☐	P (Pass)
☐	F (Fail)

D7 Do you have any other comments you would like to let us know?

APPENDIX D

Historical Information of Macquarie Lighthouse delivered by Avatar in VirSchool history lesson

Stimulus	Content
00	Introduction: Hello, my name is Mark Watson and I will be your host for the next couple of minutes. My ancestor Robert Watson was the first Lighthouse Keeper of the Macquarie Lighthouse. The Lighthouse and its keepers were an important cornerstone for the development of the then young colony.In order to understand the importance and role of the Lighthouse we need to look back in time a little bit further. We want to start our exploration of the history of the Macquarie Lighthouse with the discovery and colonization of Australia which was in the year …
01	01 Discovery of Australia 1770 - Correct. In 1770 Australia was proclaimed a British colony by Captain James Cook. Cook was a young mariner who had been on a voyage to observe the transit of Venus and afterwards explore the big southern land. Before arriving at the eastern shoreline of Australia, Cook circumnavigated New Zealand and produced highly accurate maps of the two islands. Cook first landed in Australia at a place called Botany Bay, which is a little bit south of where Sydney's main metropolitan area is located today.
02	02 Settlement 1788 - Australia was officially populated by European settlers with the arrival of the first Fleet on the 26th of January in 1788. 18 years after the discovery of Australia. Until today this day is commemorated as Australia Day and celebrated as a national holiday. Captain Arthur Phillip, the commander of the First Fleet, decided to establish a settlement at Port Jackson rather than Botany Bay. In his opinion the harbour was better suited than the original landing site of James Cook. Port Jackson is nowadays better known as Sydney Harbour.
03	03 First Flagstaff 1790 - As early as 1790 a flagstaff was erected near where the Lighthouse is located on South Head. The flagstaff served two purposes. The first and foremost purpose was to signal the arrival of a long expected ship with new supplies from England. The reason for this desperate expectation was the need for food. The colony was mostly comprised of convicts and lacked the knowledge of farmers. The second purpose of the flagstaff was to signal to the expected ship where the settlement was located and where to sail into the harbour. On the 10th of February the long awaited ship finally arrived and brought the hoped for food supplies and news from England.

03a	03a Stone Column 1790 Only four months after the arrival of the supply ship a stone column was erected near the flagstaff. This stone column was built alongside the flagstaff to increase the visibility of the landmark and serve as a dedicated look-out. At this point in time eleven people were stationed at the flagstaff and column. Several little huts were built nearby together with a garden for growing vegetables. The soldiers stationed at the lighthouse were also given a fishing boat to catch fish for themselves.
03b	03b Second Flagstaff 1792 Two things happened in 1792 with one of them being that the existing flagstaff was found to be too short. As a result, a taller flagstaff with a height over nine metres was erected nearby which could be seen from a greater distance. The second event that happened in this year was that the stone column was destroyed by a major storm. Subsequently the collapsed column was re-erected and covered with a thick coat of plaster to guard it against the weather and improve its visibility.
03c	03c Fire Beacon 1793 - 1805 In the years following the building of the second flagstaff and the re-erection of the column, a beacon light in the form of a fire was installed to guide ships approaching the harbour at night-time. The exact location of the beacon is unknown, but in 1794 an iron basket and a tripod were provided to house the fire.
04	04 First Lighthouse 1816 - 1818 Between 1816 and 1818 the first Macquarie Lighthouse was built. Before construction began under architect Francis Greenway, there was ample discussion about the position of the lighthouse, with the South and North peninsulas of Sydney Harbour being the options considered. Although North Head was strongly suggested by another sea captain, for better visibility from sea and its position closer to the natural entrance, the decision was finally made by Governor Macquarie to build the lighthouse on South Head near the existing flagstaff, column and fire beacon.
05	05 Lighthouse Keeper The lighthouse was 19.80 metres tall and in 1818 the light was installed, giving the lighthouse the finishing touch. The Macquarie Lighthouse was thus Australia's first fully operational lighthouse. Some sources even claim it to be the first lighthouse in the southern hemisphere. The lighthouse's first keeper was Robert Watson, former quartermaster and retired harbourmaster of the first fleet. Watson was appointed the position together with two helpers to assist him maintain the lighthouse. Robert Watson died only 12 months after he began his work as lighthouse keeper. Watsons Bay, an area of Port Jackson, is named in his honour.
06	06 Repairs 1822 - 1830 As early as 5 years after the end of the construction, repairs had to be conducted because parts of the building were falling apart. The causes for the decay were mostly attributed to the low quality of the sandstone and mortar. In 1822 new arches of the lighthouse were introduced on an improved principle. Furthermore, a large iron hoop was placed around the lower base of the tower, to secure the building from giving way. The building was again the subject of repairs in 1830 and a verandah was added at this time.

07	07 Dunbar 1857 - In 1857 the concerns raised with regards to the location of the lighthouse proved to be correct. Two ships were wrecked near the harbour entrance in that year. One was a passenger ship called the Dunbar. The Dunbar came in on a very stormy night and ran into the cliffs of a gap between the Macquarie Lighthouse and the entrance to the harbour. Only one man, James Johnson, survived this tragedy in which 122 people died. The other ship was a cargo ship called the Catherine Adamson which was wrecked on the other side of the harbour entrance at North Head. No one survived this disaster, which resulted in 22 fatalities.
08	08 Second Lighthouse 1880 - 1883 Eventually, the deficiencies in construction were not tolerable any more. Furthermore, a new gas powered light, which was supposed to be used, could not be installed in the old tower. Consequently, it was decided to build a new lighthouse. The new lighthouse was designed by Architect James Barnet, to closely resemble the original tower. On the 1st of March 1880 the foundation stone was laid only 3.5 metres west of the old lighthouse. The construction of the new lighthouse was finished in 1883 and a new lighting apparatus with the innovative Fresnel lens system was installed.
09	09 Powersupply 1909 - 1933 The electrical power for the new lighting apparatus was produced by two De Meritens magnetos generators. These generators were driven by an eight-horse power Crossley - otto cycle silent horizontal coal gas engine. The new light was visible up to 25 nautical miles and by 1887 the remainder of Greenway's lighthouse had been completely demolished. At the beginning of the new century, it was claimed that the gas-generated electricity was too expensive to operate the lighthouse. As a result, the lighting apparatus was replaced with a kerosene system, which was less powerful. In 1933 the system was reconverted to electricity.
10	10 Second World War 1939 - 1944 During the second world war a chain of observation posts and machine gun emplacements were built on the area surrounding the lighthouse. After the war there was rapid development in other navigational systems. The lighthouse became simply one of a number of aids, which enabled the mariner to determine his exact position. The importance of the remaining manned lighthouses such as Macquarie also decreased with the advent of integrated air sea systems.
11	11 Demanned and Today 1970's - 1980's In the 1970's and 1980's the lighthouse saw some demolition work. The surrounding keepers quarters were torn down and a number of townhouses were constructed adjacent to the lighthouse. The lighthouse was automated in 1976 and despite being demanned in 1989, it is still operational. It is nowadays operated and maintained by the "Australian Maritime Safety Authority". Public tours are organised by the "Sydney Harbour Federation Trust".

APPENDIX E

Bonferroni Adjustments

The Sub-Analyses of the results from the two display systems show that the stimuli presented in the first half of the VirSchool history lesson had statistically significant effects on the number of facts remembered correctly from the second half of the history lesson. For the Reality Center the use of 'No Music' in the first half of the VirSchool history lesson was beneficial and for the 3-monitor display system 'Music' in the first half improved memory of the facts learned in the second half. However, if an experiment is conducted a hundred times, in five of these one hundred experiments a statistically significant result will be returned by pure chance and not because the result of the experiment is truly statistically significant. For example, if we imagine that a pregnancy test produces a 'positive' result in 5% of the cases without the women taking the test actually being pregnant (so called 'false positive'), that would be the real-world equivalent of an experiment situation in which a result is returned as being statistically significant which really is not. In statistical analyses this probability is called a Type I error and can be corrected by applying a 'Bonferroni Adjustment' to the results.

The 'Bonferroni Adjustment' is a statistical method developed by Italian mathematician Carlo Emilio Bonferroni to adjust the α-criterion when performing more than one significance test (Moore *et al.*, 2006, p. 430). The following explanation describes the 'Bonferroni Adjustment' in detail.

> ***Bonferroni Adjustment.*** *When performing multiple statistical significance tests on the same data, the Bonferroni adjustment can be applied to make it more difficult for any one test to be statistically significant. For example, when reviewing multiple correlation coefficients from a correlation matrix, accepting and interpreting the correlations that are statistically significant at the conventional .05 level may be inappropriate, given that multiple tests are performed.*

Specifically, the alpha error probability of erroneously accepting the observed correlation coefficient as not-equal-to-zero when in fact (in the population) it is equal to zero may be much larger than .05 in this case.

The Bonferroni adjustment usually is accomplished by dividing the alpha level (usually set to .05, .01, etc.) by the number of tests being performed. For instance, suppose you performed multiple tests of individual correlations from the same correlation matrix. The Bonferroni adjusted level of significance for any one correlation would be:

$.05 / 5 = .01$

Any test that results in a p-value of less than .01 would be considered statistically significant; correlations with a probability value greater than .01 (including those with p-values between .01 and .05) would be considered non-significant. (Hill et al., 2006, p. 572)

In the present experiment, the number of tests (the denominator in the above example formula) is thus determined by the number of individual correlations of the correlation matrix (see Table 12).

Table 12: Correlation Matrix of Music/No Music First and First/Second Half of the VirSchool history lesson

	Music First	**No Music First**
First Half	First Half/Music First	First Half/No Music First
Second Half	Second Half/Music First	Second Half/No Music First

Because in the present scenario a 2x2 correlation matrix was used with two variables ('First Half' and 'Second Half' of the VirSchool history lesson) that can each take two possible values ('Music First' and 'No Music First'), the number of tests being performed is 4, the product of the 2x2 correlation matrix. The resulting Bonferroni adjusted level of significance for the present correlation matrix is thus calculated by dividing the alpha level by 4. Hence, the complete formula for calculating the Bonferroni adjusted significance level is

$.05 / 4 = .0125$

Based on the above, we argue that a p-value of .0125 is an appropriate criterion on which to interpret the results of the Reality Center and the 3-monitor display system. This means that any analysis of the present experiment data that produces a p-value of less than .0125 can safely be considered statistically significant. The remainder of this discussion is based on this value. Again the data analysis is split between the two display systems.

Descriptive Statistics

	Condition...	Caveor...	Ge...	La...	Mean	Std. Deviation	N
Total.1	Music First	Cave	1	1	11.00	.	1
				2	7.00	1.414	2
				Total	8.33	2.517	3
			2	1	8.00	4.243	2
				2	6.43	.976	7
				Total	6.78	1.856	9
			Total	1	9.00	3.464	3
				2	6.56	1.014	9
				Total	7.17	2.038	12
		3-Monitor	1	1	10.00	1.826	4
				2	8.67	4.041	3
				Total	9.43	2.760	7
			2	1	8.33	1.528	3
				2	7.50	.707	2
				Total	8.00	1.225	5
			Total	1	9.29	1.799	7
				2	8.20	2.950	5
				Total	8.83	2.290	12
		Total	1	1	10.20	1.643	5
				2	8.00	3.082	5
				Total	9.10	2.601	10
			2	1	8.20	2.387	5
				2	6.67	1.000	9
				Total	7.21	1.718	14
			Total	1	9.20	2.201	10
				2	7.14	1.994	14
				Total	8.00	2.284	24
	Silence First	Cave	1	1	7.00	.	1
				2	6.40	3.435	5
				Total	6.50	3.082	6
			2	1	5.00	.	1
				2	8.20	3.421	5
				Total	7.67	3.327	6
			Total	1	6.00	1.414	2
				2	7.30	3.368	10
				Total	7.08	3.118	12
		3-Monitor	1	1	10.00	4.830	4
				Total	10.00	4.830	4
			2	1	7.00	.000	2
				2	7.50	2.345	6
				Total	7.38	1.996	8
			Total	1	9.00	4.050	6
				2	7.50	2.345	6
				Total	8.25	3.251	12
		Total	1	1	9.40	4.393	5
				2	6.40	3.435	5
				Total	7.90	4.040	10
			2	1	6.33	1.155	3
				2	7.82	2.750	11
				Total	7.50	2.534	14
			Total	1	8.25	3.732	8
				2	7.38	2.941	16
				Total	7.67	3.171	24
	Total	Cave	1	1	9.00	2.828	2
				2	6.57	2.878	7
				Total	7.11	2.892	9
			2	1	7.00	3.464	3
				2	7.17	2.368	12
				Total	7.13	2.475	15
			Total	1	7.80	3.033	5
				2	6.95	2.505	19
				Total	7.12	2.576	24
		3-Monitor	1	1	10.00	3.381	8
				2	8.67	4.041	3
				Total	9.64	3.414	11
			2	1	7.80	1.304	5
				2	7.50	2.000	8
				Total	7.62	1.710	13
			Total	1	9.15	2.911	13
				2	7.82	2.523	11
				Total	8.54	2.766	24
		Total	1	1	9.80	3.155	10
				2	7.20	3.190	10
				Total	8.50	3.364	20
			2	1	7.50	2.138	8
				2	7.30	2.179	20
				Total	7.36	2.129	28
			Total	1	8.78	2.922	18
				2	7.27	2.504	30
				Total	7.83	2.739	48

Total.2	Music First	Cave	1	1	9.00	.	1
				2	6.00	2.828	2
				Total	7.00	2.646	3
			2	1	7.50	3.536	2
				2	6.00	1.915	7
				Total	6.33	2.179	9
			Total	1	8.00	2.646	3
				2	6.00	1.936	9
				Total	6.50	2.195	12
		3-Monitor	1	1	10.50	1.291	4
				2	10.33	2.517	3
				Total	10.43	1.718	7
			2	1	11.33	1.155	3
				2	9.50	.707	2
				Total	10.60	1.342	5
			Total	1	10.86	1.215	7
				2	10.00	1.871	5
				Total	10.50	1.508	12
		Total	1	1	10.20	1.304	5
				2	8.60	3.286	5
				Total	9.40	2.503	10
			2	1	9.80	2.864	5
				2	6.78	2.279	9
				Total	7.86	2.825	14
			Total	1	10.00	2.108	10
				2	7.43	2.709	14
				Total	8.50	2.750	24
	Silence First	Cave	1	1	6.00	.	1
				2	10.00	2.449	5
				Total	9.33	2.733	6
			2	1	7.00	.	1
				2	9.40	3.362	5
				Total	9.00	3.162	6
			Total	1	6.50	.707	2
				2	9.70	2.791	10
				Total	9.17	2.823	12
		3-Monitor	1	1	11.00	2.944	4
				Total	11.00	2.944	4
			2	1	8.00	1.414	2
				2	6.67	1.751	6
				Total	7.00	1.690	8
			Total	1	10.00	2.828	6
				2	6.67	1.751	6
				Total	8.33	2.839	12
		Total	1	1	10.00	3.391	5
				2	10.00	2.449	5
				Total	10.00	2.789	10
			2	1	7.67	1.155	3
				2	7.91	2.844	11
				Total	7.86	2.538	14
			Total	1	9.12	2.900	8
				2	8.56	2.828	16
				Total	8.75	2.801	24
	Total	Cave	1	1	7.50	2.121	2
				2	8.86	3.024	7
				Total	8.56	2.789	9
			2	1	7.33	2.517	3
				2	7.42	3.029	12
				Total	7.40	2.849	15
			Total	1	7.40	2.074	5
				2	7.95	3.027	19
				Total	7.83	2.823	24
		3-Monitor	1	1	10.75	2.121	8
				2	10.33	2.517	3
				Total	10.64	2.111	11
			2	1	10.00	2.121	5
				2	7.38	1.996	8
				Total	8.38	2.364	13
			Total	1	10.46	2.066	13
				2	8.18	2.442	11
				Total	9.42	2.483	24
		Total	1	1	10.10	2.424	10
				2	9.30	2.830	10
				Total	9.70	2.598	20
			2	1	9.00	2.507	8
				2	7.40	2.604	20
				Total	7.86	2.635	28
			Total	1	9.61	2.453	18
				2	8.03	2.785	30
				Total	8.62	2.749	48

APPENDIX F

On 16/08/2009, at 10:12 AM, John Sweller wrote:

Which makes your result even more interesting! Your explanation seems plausible to me but I doubt there is any literature on it. In effect, you are saying that being placed in an unfamiliar environment consumes WM [Working Memory] resources because we automatically attend to novel aspects of that environment until we feel confident we "understand" it. I'd urge you to publish your results. They are very interesting.

Professor John Sweller

From: Eric Fassbender
Sent: Sunday, August 16, 2009 10:17 AM
To: John Sweller
Subject: Re: Can large and unfamiliar immersive display systems cause cognitive overload?

Dear John,

Thank you very much for your answer, however, I think I have made a mistake. I should have mentioned that participants did not have to learn anything in order to operate the Reality Center. They were just watching a computer animated movie with historical information that they were asked to learn as good as possible. One group of participants did this in the Reality Center and another group on the much smaller 3-monitor display system.

The curious thing is that the group in the 3-monitor display system remembered statistically significantly more information than the group in the Reality Center and I am asking myself whether the unfamiliarity and size of the bigger Reality Center might have overwhelmed participants and consumed cognitive resources?

I have observed 96 participants in this display system before switching to the smaller 3-monitor display system and as soon as the first participant sat down in front of the 3-monitor display system I instantly felt that he approached the 3-monitor display system in a different way. And it was the same with the other participants. They seemed to be much more comfortable with the setup. You know, I think that participants in the Reality Center were thinking "What is this thing and what is the purpose of this experiment? What am I supposed to do?, etc.".

However, because I only switched display systems due to equipment failure of the Reality Center I had no measures in the questionnaire to investigate the difference in performance between display systems and I am now trying to find an explanation for this unexpected result.

I would very much value your thoughts. Thank you for your time,

Eric

On 15/08/2009, at 5:23 PM, John Sweller wrote:

Dear Eric

Yes, for new technology, students need to become familiar with that technology prior to it being used to learn something else. Learning how to use the technology and learning the curriculum area information simultaneously can impose an overwhelming cognitive load. The technology and the curriculum area should be learned serially rather than simultaneously.

The paper was published as:

Clarke, T., Ayres, P. & Sweller, J. (2005). The impact of sequencing and prior knowledge on learning mathematics through spreadsheet applications. Educational Technology Research and Development, 53,
15-24.

Best of luck for your PhD.

John

From: Eric Fassbender
Sent: Saturday, August 15, 2009 5:30 PM
To: John Sweller
Subject: Can large and unfamiliar immersive display systems cause cognitive overload?

Dear Professor Sweller,

My name is Eric Fassbender and I am researching the effect of music on learning in Virtual Environments. As part of my research I have used two different display systems, a 3-monitor display system and a Reality Center (see attachments), and I found that participants in the smaller, less immersive 3-monitor display system performed better in a memory task. My thinking is that this may be due to the fact that participants were unfamiliar with the Reality Center and overwhelmed by the technology which most of them would have probably not experienced before. Is there any evidence that shows that new and unfamiliar technology (in this case a rather big and maybe daunting display system in an otherwise completely dark room) might overwhelm participants to the level that it affects their memory performance?

I would very much appreciate your answer,

Eric Fassbender

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