Ecological Validation of Virtual Reality Mall Cognitive Assessment and Evaluation

A Dissertation submitted in partial fulfillment of the requirements
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In
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DECLARATION

I hereby certify that the work which is being presented in the thesis entitled, **"Ecological Validation of Virtual Reality Mall Cognitive Assessment and Evaluation"** in the partial fulfillment of the requirements for the award of Master of Engineering in Electronics Instrumentation and Control Engineering submitted in Electrical and Instrumentation Engineering Department, Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of **Mr.Sushil Chandra**, Scientist 'F' Institute of Nuclear Medicine and Allied Science (INMAS),DRDO,New Delhi and **Dr.Ravinder Agarwal**,professor, Department of Electrical and Instrumentation Engineering, Thapar University, Patiala, Punjab.

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ABSTRACT

Virtual reality has the advantage of being able to implement specific circumstances or situations just like a real environment. Virtual Reality (VR) technology is being widely recognized as a potential tool for the assessment and rehabilitation of human cognitive and functional processes. Virtual Environments (VE) are dynamic stimulus environments, in which all executive function abilities can be recorded. It is not just interesting for games and defense applications but, is also known for its usage in the medical field.

The commonly employed paper and pencil test used to assess executive functions was inadequate due to its limited ecological validity. A novel task has been done using Virtual Reality Mall (VRM) to assess executive function abilities, for this a group of 30 graduate students aged between 20-25 years, perform various tests such as VRM, BADS test (Rule Shift Card)and the Tower of London test. Another group composed of 10 working employees, belonging to the age group 30-40 years performs the same tests as the graduate students and results were analyzed. Analysis of these working employees' data shows a decline in the VR score performance relative to the graduate students. The ecological validity of VRM scores is confirmed with the help of Tower of London tests.

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Chapter-1
Introduction

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Virtual Reality (VR) technology is being widely recognized as a potential tool for the assessment and rehabilitation of human cognitive and functional processes. Virtual Environments (VE) are dynamic stimulus environments, in which all executive function abilities can be recorded. It is not just interesting for games and defense applications but, is also known for its usage in the medical field. This technology potentially offers testing and training options that were unavailable with the use of conventional neuropsychological methods [1]. It is believed that computer-generated interactive simulated environments can be used to assess and rehabilitate cognitive abilities [2]. Virtual reality has the advantage of being able to implement the specific circumstance or situation just like a real three-dimensional environment under a virtual environment using a computer. For example, the practice of functional skills, such as street crossing or supermarket and social phobia [3, 9], were inconvenient and sometimes dangerous for subjects when they take place in real settings. The individuals who suffer from executive function impairments exhibit different problems, such as starting and stopping activities or inability of mental and behavioral shifts [10]. Here our aim is to assess executive functioning abilities(such as planning, problem solving, organizing etc.) and analyze its ecological validity, between the members of two different age groups, using VRM and executive function tests(TOL, Rule Shift Card). Executive functions is an umbrella term for cognitive processes that control, and manage other cognitive processes, such as planning, initiatives, problem solving, prioritizing, paying attention, focusing on important details, working toward a goal, and initiation and monitoring of actions, shifting and stopping a finished action or task. In the past, the assessment and rehabilitation of executive functions has been performed under typical clinical or laboratory settings, via pen and paper tests. The lack of ecological validity had also been a drawback for experimental tasks and traditional neuropsychological tests [11, 14]. In the present study virtual reality mall (VRM) was created using the software's: 3D Studio Max from Autodesk (www.autodesk.com) and Vizard (www.world Viz.com) [15, 18].

1.1 Background

The human cognition is measured by the different kind of sensors. Now a day's new technology to assess a person's cognitive state in near real time. It is now possible to integrate this new technology into real-world, real-time system to assess cognitive ability across a wide range of application domains including clinical, industry, military and gaming. This thesis utilizes virtual reality techniques to bridge the gap between standardization and ecological validity in executive function research.

1.2 Motivation

Many people suffered from attention deficit disorder and concentration problems. They have been easily distracted by the others means not having fully concentration and attention power. So to overcome these problems we used the fully immersive technology i.e. VR. The change in environment usually affects the cognitive ability of a person and sometimes the impact is negative that leads to decrement in the cognition level. For instance, in military some soldiers suffer from stress and depression because of the unsuitable environment. Now, there must be some measures to enhance their cognitive ability. This need gives an idea for our research work in which we were going to assess the cognition ability of individual and then attempts to increase the level by providing the virtual reality environment. The change in environment usually affects the cognitive ability of a person and sometimes the impact is negative that leads to decrement in the cognition level.

1.3 Objectives

Virtual Reality (VR) enhances the cognitive ability of the individual by putting them into the Virtual Environment. Virtual Reality Mall (VRM) was designed to assess execute function ability to purchasing items between graduate student groups and working employees, like developing initiatives, making appropriate decisions, working memory, prioritizing, paying attention, focusing on important details, working toward a goal, shifting (to the next steps of a task or to the next task) and stopping a finished action .The various variables of virtual environment and executive function test give the information about their executive function ability.

1.4 Organization of Thesis

The Thesis is organized as follows:

Chapter1 gives the general **“Introduction”** of the research work, its background and Objectives.

Chapter2 deals with **“Literature Review”** i.e., overview of the work done. Is about the related Work and gives an overview of work done by the Researcher’s in the field of Virtual Reality.

Chapter3 deals with **“Anatomy of Brain”,** it gives the general introduction about human Brain and **Executive Function.**

Chapter4 deals with **“Introduction of the Virtual reality”** and its related contents.

Chapter5 gives the overview of the **Hardware, Software and the Programming languages.**

Chapter6 explains the **“Proposed Methodology”** by giving an overview of the Virtual Reality Mall.

Chapter7 deals with **Result and discussion** between groups.

Chapter8 deals with “**Conclusion and Future Recommendation**”.

Chapter-2
Literature Review

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There were many research studies that have been conducted for examining the effect of Virtual Reality Environments. A number of them were also related to cognitive psychology. In this section, related studies will be mentioned briefly.

J. Galen Buckwalter, Jocelyn S. McGee, describes the progress of a VR research program at the USC Integrated Media Systems Center and Information Sciences Institute that has developed and investigated the use of a series of VEs designed to target (i) molecular visuo spatial skills using a 3-D, projection-based desk system, and (ii) attention (and soon memory and executive functioning) processes within ecologically valid functional scenarios utilizing a head-mounted display (HMD) [1].

Giuseppe Riva, the current state of clinical research relevant to the development of virtual environments for use in psychotherapy. In particular, the paper focuses its analysis on both actual applications of VR in clinical psychology and how different clinical perspectives can use this approach to improve the process of therapeutic change [2].

Laura Carelli, establishes ecological validity and initial construct validity of the virtual reality version of the Multiple Errands Test based on NeuroVR software as an assessment tool for executive functions. In particular, the Multiple Errands Test is an assessment of executive functions in daily life which consists of tasks that abide by certain rules and is performed in a shopping mall-like setting where there were items to be bought and information to be obtained [3].

Bo Ryun Kim, investigated the effect of virtual reality on the recovery of cognitive impairment in stroke patients [4]. **Soledad Quero**, presented the work to show the utility of this system for the treatment of a storm phobia [5]. **Rizzo, J G Buckwalter**, outlines the application of a virtual environment for the study, assessment, and possible rehabilitation of a visuo spatial ability referred to as mental rotation. The rationale for the Virtual Reality Spatial Rotation (VRSR) system is discussed [6].

T Maria, rehabilitation specialists were often given the task of determining capacity to drive. However, traditional assessment methods were fraught with various limitations, including dependence on subjective interpretation of behaviors, non-standardized procedures, and few ecologically valid measures. A virtual reality-based driving-assessment system (VR-DAS) offers the opportunity to overcome many of the limitations of current methodologies. Specially, a VR-DAS permits the development of relevant driving scenarios that can provide objective and quantiable measures of driving behaviors, allowing for increasing Standardization and consistency of protocols. VR-DAS also allows for the creation of realistic and interactive driving scenarios at varying levels of challenge and complexity [7].

Evelyne Klinger, reported the definition of a VR-based clinical protocol and a study to treat social phobia using virtual reality techniques. The virtual environments used in the treatment reproduce four situations that social phobic feel the most threatening: performance, intimacy, scrutiny and assertiveness. With the help of the therapist, the Patient learns adapted cognitions and behaviors when coping with social situations, with the aim of reducing her or his anxiety in the corresponding real life situations [8].

Naomi Josman, Esther Hof, Evelyne Klinger, The objectives of this study were to examine the feasibility of using a virtual supermarket to assess and treat executive function deficits for people who have had a stroke, and to explore the relationships between performance within the virtual supermarket and executive functions. The virtual supermarket used in this study runs on a desktop computer and is easy to operate in typical clinical settings [9].

Daniela Schneider Bakos, This study aimed at investigating differences in the performance of the young elderly and oldest old in tasks evaluating cognitive flexibility/inhibition (Stroop test), selective attention/working memory (Digit Span Subtest), premorbid intelligence/semantic knowledge (Vocabulary Subtest), and decision making [10].

Leilani Doty describes executive function, brain-controlled functions that guide various functions of the body such as planning, solving problems, organizing and directing the body to carry out daily activities. In addition executive function involves developing initiatives, making appropriate decisions, considering consequences, working memory, prioritizing, paying attention (and not being distracted), focusing on important details, working toward a goal, shifting (to the next steps of a task or to the next task), and stopping a finished action or task [11].

Nick alderman, Burgess, The aim of this study was to ascertain the value of a simplified version of the MET (MET–SV) for use with the range of people more routinely encountered in clinical practice. Main findings were as follows: 1) The test discriminated well between neurological patients and controls, and the group effects remained when the difference in current general cognitive functions (WAIS–R FSIQ) was taken into account. 2) The best predictors of performance in the healthy control group were age and the number of times participants asked for help (with more requests associated with poorer performance.3)In the neurological group, two clear patterns of failure emerged, with performance either characterized by rule breaking or failure to achieve tasks. These two patterns were associated with different dysexecutive symptoms in everyday life.4) the patients not only made more errors than controls, but also different ones. A scoring method that took this into account markedly increased test sensitivity.5) Many patients passed traditional tests of executive frontal lobe function but still failed the MET–SV. This pattern was strongly associated with observed dysexecutive symptoms in everyday life [12].

Paulw. Burgess, Nick Alderman and Jon Evans, studied ninety-two mixed neuropsychological patients using neuropsychological tests, to knew the patients well (relatives) completed a questionnaire about the patient's Dysexecutive problems in everyday life, and this paper reports the extent to which the tests predicted the patients' everyday life problems. All of the tests were significantly predictive of at least some of the behavioral and cognitive deficits reported by patients' carers. However, factor analysis of the patients' Dysexecutive symptoms suggested a fractionation of the Dysexecutive syndrome, with neuropsychological tests loading differentially on 3 underlying cognitive factors (Inhibition, Intentionality, and Executive Memory), supporting the conclusions that different tests measure different cognitive processes, and that there may be limits to the fractionation of the executive system. [13]

Tamar Weiss and Evelyne Kliger, created a completely new clinical paradigms which would have been hard to achieve in the past. In applications of rehabilitation for both motor and cognitive deficits the main focus of much of the early exploratory research has been to investigate the use of virtual reality as an assessment tool. To date such environments were primarily: (a) single user (*i.e.*, designed for and used by one clinical client at a time) and (b) used locally within a clinical or educational setting. More recently, researchers have begun the development of new and more complex VR-based approaches according to two dimensions: the number of users and the distance between the users. Driven by a push-pull phenomenon, the original approach has now expanded to three additional avenues: multiple users in co-located settings; single users in remote locations; and multiple users in remote locations [14].

M. Kurtz1 Matthew, Elizabeth Baker, developed virtual reality (VR) assessment of medication management skills, the Virtual Reality Apartment Medication Management Assessment (VRAMMA), is investigated in 25 patients with schizophrenia and 18 matched healthy controls. The VRAMMA is a virtual 4-room apartment consisting of a living room with an interactive clock and TV, a bedroom, a kitchen, and a bathroom with an interactive medicine cabinet. After an exploratory phase, subjects were given a mock prescription regimen to be taken 15 minutes later from pill bottles located in the medicine cabinet in the bathroom of the virtual environment. The VRAMMA is administered with a validated measure of medication management skills, several neurocognitive tests, and a symptom scale [15].

Daniel Freeman, Seven applications of virtual social environments to schizophrenia are set out: symptom assessment, identification of symptom markers, establishment of predictive factors, tests of putative causal factors, investigation of the differential prediction of symptoms, determination of toxic elements in the environment, and development of treatment. The initial VR studies of persecutory ideation, which illustrate the ascription of personalities and mental states to virtual people, are highlighted. VR, suitably applied, holds great promise in furthering the understanding and treatment of psychosis [16].

H. Logie Robert and G. Pearson David, did one experiment to describe that examined the possible involvement of working memory in the Virtual Errands Test which requires subjects to complete errands within a virtual environment, presented on a computer screen. Time is limited, therefore subjects had to swap between tasks (multitask) efficiently to complete the errands or asked to randomly generate months of the year aloud in the dual-task condition, while another 21 were asked to suppress articulation by repeating the word “December”. An overall dual-task effect on the Virtual Errands Test is observed, although this is qualified by an interaction with the order of single and dual-task conditions [17].

Shih-Ching Yeh, made virtual reality(VR) technology to develop a novel diagnosis & assessment system, which uses head mounted display(HMD), game technology and sensors to generate an interactive and panoramic scenario—a virtual convenience store—for assessment of executive functions and memory. A variety of tasks of multi-layered difficulty-level hierarchy, such as memorizing a shopping list, looking for certain goods, and checking out, has been designed for customized and adaptive assessment, training, and treatment of MD [18].

M. Krijn, Research on treatment for anxiety disorders is discussed in this article, and the mediating and moderating variables that influence VR treatment effectiveness as well. Evidence is found that VRET is effective for participants with fear of heights and of flying. For other phobias, research to date is not conclusive. More randomized clinical trials in which VRET is compared with standard exposure are required. Furthermore, studies are needed in which VRET is not just a component of the treatment package evaluated, but in which VRET should be assessed as a stand-alone treatment [19]. **Evonne Shek ,** describe 'significant impaired decision-making ability' with regard to treatment for mental disorder: an empirical analysis [20].

Michelle Wang Denise Reid presents the current status and use of virtual reality (VR) for children with attention deficit hyperactivity disorder (ADHD), autism and cerebral palsy. This literature review explores how VR systems have been used as treatment tools to address the primary impairments of these disorders. Three major classes of VR display systems are identified that can be characterized by the type of human-computer interaction provided: (1) feedback-focused interaction, (2) gesture- based interaction, and (3) haptic-based interaction [21].

Carol S. Emerson, observed the effects of anxiety and depression on frontal lobe functioning. In order to assess the effects of anxious-depression on cerebral functioning performance on the Trail Making Test (Forms A and B) and on the Concept Formation subtest of the Woodcock Johnson is compared between groups. As predicted, anxious-depressed boys demonstrated deficits in sequencing, alternation, and problem-solving tasks as evidenced by longer completion times and significantly more errors on the tests [22].

Alessandro P Silva, describes the development and the testing of a virtual environment that is capable to quantify the influence of red green versus blue-yellow color stimuli on the performance of people in a fun and interactive way, being appropriate for the target audience [23]. **Jarrell Pair and Albert Rizzo**, represent both extremes of the assessment spectrum—basic paper tests/rating scales and high level simulation technology—for the measurement of vastly different criterion performance. The VRCPAT is envisioned to fill the middle ground between these two poles by creating a battery of VR-delivered performance tests that will serve to generate a normative database for performance evaluation and comparison [24].

I. Kim Sun, study the effect of Virtual Reality Cognitive Training for Attention Enhancement; they performed research on healthy person and also those persons that were having some problems to perceive the things [25]. **L.H. Phillips,** describe the role of memory in the tower of London task. The Tower of London (TOL) task is widely used as a neuropsychological test of planning. Relatively little is known of the cognitive components of the task, and in particular the role of memory in performance. The current studies on normal adults looked at the role of verbal and spatial working memory in the TOL. The effects of verbal and visuo spatial dual-task manipulations on TOL performance were examined in an experiment with 36 participants. Both verbal and visuo spatial executive secondary tasks caused poorer performance on the TOL; however, concurrent articulatory suppression enhanced performance [26].

Barbara A Wilson, describe a test battery designed to assess the effects of dysexecutive syndrome, a cluster of impairments generally associated with damage to the frontal lobes of the brain. These impairments include difficulties with high-level tasks such as planning, organizing, initiating, monitoring and adapting behavior [27].

Rizzo, in a virtual classroom studied a virtual reality environment for the assessment and rehabilition of attention deficits for this they used a basic virtual environment as a classroom [28].

Diana Jovanovski , developed - the Multitasking in the City Test (MCT) – in an attempt to improve ecological validity. The MCT involves task demands that resemble the demands of everyday activities. In study one; healthy subjects were recruited in order to explore ‘normal’ performance on the MCT and its relationship with other cognitive measures. The MCT showed poor associations with executive tests and significant correlations with nonexecutive tests. This suggested the MCT may evaluate executive functioning in a different way from other executive measures such that it does not simply measure component executive processes but the integration of these components into meaningful behavior [29].

Chapter 3
Anatomy of Brain

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This chapter explains the basic concepts encountered in the research work. Also, this chapter gives a brief introduction of brain and executive function.

3.1 Basis for Cognitive Science

Cognitive science is the interdisciplinary scientific study of the brain and its processes. It examines what cognition is, what it does and how it works. It includes research on intelligence and behavior, especially focusing on how information is represented, processed, and transformed (in faculties such as perception, language, memory, reasoning, and emotion, executive function) within nervous systems (human or other animal) and machines (*e.g.* computers).

3.2 Brain

The brain is the most complex organ in the human body. Human brain grows up to 75-80% of the adult size with in the first two years and full size at the age of 6 years. It is situated in a bony case called cranium which protest it from injuries. Brain is covered with cranial meninges. Human brain is wrinkled surface and pinkish grey in color. It is formed of more than 100 billion nerve cells called neurons. Since each neuron can connect with about 25,000 other cells there were about 2.5 million billions inter linked nerve connection in the brain.

The brain is comprised of a number of different regions, each with specialized functions. In humans, its size and function has increased rapidly. While the older portions of the brain remain relatively static. It has three main parts:

3.2.1 The cerebellum sits at the back of your head, under the cerebrum. It controls coordination and balance.

3.2.2 The brain stem sits beneath your cerebrum in front of your cerebellum. It connects the brain to the spinal cord and controls automatic functions such as breathing, digestion, heart rate and blood pressure.

3.2.3 The cerebrum fills up most of your skull. It is involved in remembering, problem solving, thinking, and feeling. It also controls movement.

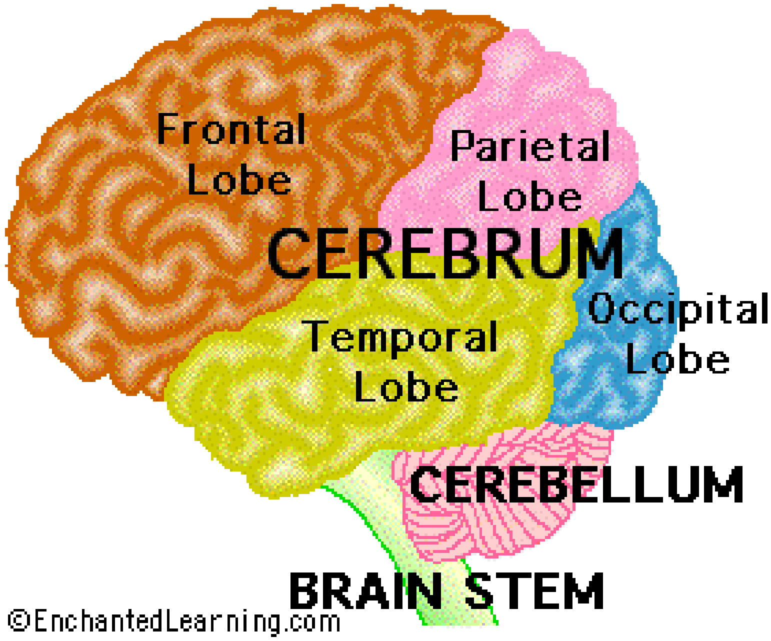

Fig 3.1 Major parts of the brain

The Forebrain (Cerebrum) is largest part and is in the front portion. Its main function includes hearing, reasoning, and problem solving initiation of movement, coordination of movement, sensing temperature and touch, executive function. It is divided by a longitudinal fissure into two hemispheres, each containing four lobes. The frontal, temporal, parietal, and occipital lobes cover the brains surface. But here researcher will discuss only frontal lobes. Because our thesis work is center around executive function.

3.2.3.1 Frontal Lobes

The frontal lobe is an area in the brain of mammals, located at the front of each cerebral hemisphere and positioned anterior to (in front of) the parietal lobe and superior and anterior to the temporal lobes. It is separated from the parietal lobe by a space between tissues called the central sulcus, and from the temporal lobe by a deep fold called the lateral sulcus. The executive functions of the frontal lobes involve the ability to recognize future consequences resulting from current actions, to choose between good and bad actions (or better and best), override and suppress socially unacceptable responses, and determine similarities and differences between things or events, executive function.

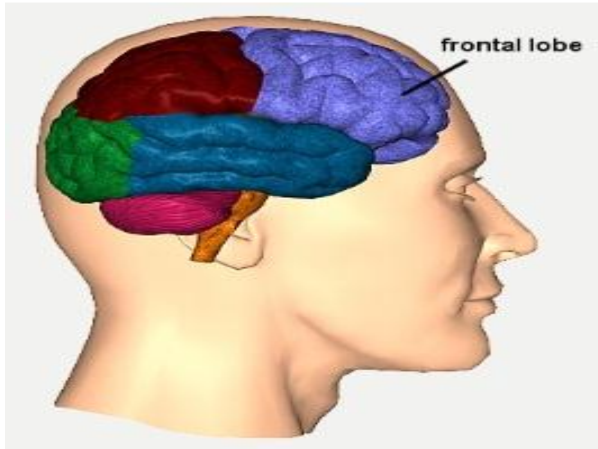

Fig 3.2 Frontal lobe of the brain

3.3 Executive Function

This is the brain-controlled functions that guide various functions of the body such as executive function, solving problems, organizing and directing the body to carry out daily activities. In addition executive function involves developing initiatives, making appropriate decisions, considering consequences, working memory, prioritizing, paying attention (and not being distracted), focusing on important details, working toward a goal, shifting (to the next steps of a task or to the next task), and stopping a finished action or task [12].

The executive functions of the frontal lobes handle executive function and paying attention to important needs and actions of the body. Executive function include: controlling, starting, stopping, regulating, adjusting to change, executive function when faced with new settings or situations, forming ideas, storing information in and accessing it from working memory, controlling emotions, and thinking abstractly.

For example executive function includes:

- What to do?
- When to shift to the second step,
- When to stop the completed task and then move on to a different activity,

3.3.1 Executive Function: Main Steps

Another look at the multiple steps of executive function provides an example of the high, intricate level of executive function work in the brain:

Step 1. Start: Think about the problem and what needs to be done. Think of a way to solve the problem. Consider resources, past experience, new possibilities, values, deadlines, etc.

Step 2. Maintain: Start acting on the first step and continue until that step is done.

Step 3. Switch: Do each step and move on to the next step in order to complete the task or solve the problem.

Step 4. Stop: Evaluate the outcome. Is the end result good, is it adequate, is it finished, or is more action needed? When done, then stop

Chapter 4
Virtual Reality

4.1 Introduction

Virtual Reality (VR) involves development of a computer generated virtual environment intended to simulate the real world. It is an emerging computer visualization technology that allows users to experience a strong sense of reality in a computer-generated environment. Engineers have begun to realize the usefulness of VR as an innovative tool to visualize, manipulate, and interact with complex three-dimensional (3-D) graphical data that were difficult or even impossible to adequately understand in traditional two-dimensional (2-D) drawings or even 3-D solid models. This chapter discusses the recent developments and applications of VR in engineering and the sciences.

VR can be defined as an integrated quartet of "Immersion-Interaction-Imagination-Interest". VR simulates the action perception relationship in a physically correct manner but without involving real objects or real events. VR is now being developed and validated to focus on component cognitive processes including: attention and alertness process, spatial abilities, learning and memory, anxiety disorders [19, 24]. The ability of Virtual Environments (VE) to create dynamic, immersive, three dimensional stimulus environments, in which all behavioral responding can be recorded, offers assessment and rehabilitation options that were not available using traditional assessment methods. Much like aircraft simulators have been developed to assess and train piloting ability under a range of controllable stimulus conditions. Virtual reality can be defined as a class of computer controlled multisensory communication technologies that allow more intuitive interactions with data and involve human senses in new ways. This technology enables the people to deal with information more easily [25]. VR provides a different way to see and experience information, one that is dynamic and immediate. It is also a tool for model building and problem solving. The virtual world is interactive; it responds to the user's action. Virtual Reality evokes a feeling of immersion, a perceptual and psychological sense of being in the digital environment presented to the senses.

4.2 VR History

VR is a change in display technology. The idea of inclusion of VR within an artificial environment is not new .In fact VR can be considered an extension of ideas which have been around for some considerable time such as flight simulation, and wide screen projectors. Using such systems, the viewer is presented with a screen which takes up a large portion of the visual field giving a powerful sense of presence.

Two major breakthroughs occurred in the 1960's with the arrival of minicomputer and the work of Ivan Sutherland in 1965 entitled "The Ultimate Display", Sutherland prophesied the development of first HMD, which was later achieve with the HMD called "The Sword of Damocles". Sutherland also realized the potential of computers to generate images for flight simulation where previously images were generated using video camera. These ideas were combined by two NASA Ames Scientists, Fisher and McGreevy, working on a project called the 'Virtual Workstation' in 1984. From these ideas NASA developed the first commercially viable HMD, called the Visual Environment Display (VIVED) which is based on scuba divers face mask with the optical screen displays supplied from two Sony Watchman hand held televisions. This development is unprecedented as NASA had an HMD that could be produced at an affordable price and the VR industry is born.

4.3 Importance of Virtual Reality

There is a growing body of research that can provide a strong rationale for VR as the next Human-Computer Interface. As an interface metaphor, VR clearly has tremendous potential.

- **3D Perception**: The shape of objects and associated interrelationships remain ambiguous without true three-dimensional representation. The perspective projection onto a flat surface on a normal computer screen can be unclear. VR removes this ambiguity, and therefore represents a fundamental objective in design processes. Of particular importance is the sense of scale that can only be conveyed by immersing the analyst or designer in the "design" itself.
- **Communication**: VR promises to completely revolutionize the use of computers for cooperative work interaction. Natural human interaction is not

easily achievable in two dimensions. The telephone or videophone is effective but limited. When subjects share a common location, they have the freedom to more easily and naturally communicate ideas (i.e. engineers from Japan and Germany simultaneously discussing a model of a car in the design process). When multiple subjects were involved then the VR environment is said to be a Collaborative Virtual Environment (CVE).

4.4 Types of VR System

VR system can be classified into three categories. Each category can be ranked by the sense of immersion or degree of presence it provides. Immersion or presence can be regarded as powerful in the attention of the user to focus on the task in hand. Immersion presence is generally believed to the product of several parameters including level of interactivity, image complexity, stereoscopic view, and field of regard and the update rate of the display.

4.4.1 Desktop Virtual Reality

When 3D graphical virtual world is displayed on a standard computer screen, it is called as Desktop Virtual Reality (DVR) in which PCs and workstations can be used as screen-based VR system. Using the desktop system, the virtual environment is viewed through a portal or window by utilizing a standard high resolution monitor. After invention of LED display system the resolution and depth of immersion increased. The 3D displays can be seen by special goggles. Interaction with the virtual environment can occur by conventional means such as keyboards, mice and trackballs or may be enhanced by using 3D interaction devices. The desktop VR system has advantage that they have good level of graphics performance, no special hardware is required. These systems can be regarded as the lowest cost VR solution which can be used for many applications.

4.4.2 Semi-Immersive Projection System

Semi-immersive systems were a relatively new implementation of VR technology and borrow considerably from technologies developed in the flight simulation field. A semi-immersive system will comprise a relatively high performance graphics computing system which can be coupled with one of the following.

- A large screen monitor
- A large screen projector system
- Multiple television projection systems

By using a wide field of view, these systems can increase the feeling of immersion or presence experienced by the user. However, the quality of the projected images is an important consideration.

4.4.3 Fully Immersive Head-Mounted Display Systems:

The most direct experience of virtual environments is provided by fully immersive VR systems. These systems were probably the most widely known VR implementation where the user either wears an HMD or uses some form of head-coupled display.

The HMD uses small monitors placed in front of each eye which can provide stereo, bi ocular or monocular images. Stereo images were provided in a similar way to shutter glasses, in that a slightly different image is presented to each eye. The major differences is that the two screens were placed very close (50-70 mm) to the eye, although the image, which the wear focuses on, will be much further away because of the HMD optical system. Bi-ocular images can be provided by displaying identical images on each screen and monocular images by focusing only one display screen. The most commonly used displays were small Liquid Crystal display (LCD) panels but more expensive HMDs use Cathode Ray tubes (CRT) which increase the resolution of the image.

4.5 Application of VR

VR has application in cognitive enhancement, architecture and construction, education and training, business marketing, medical, military and entertainment.

4.5.1 In the military: This is particularly useful for training soldiers for combat situations or other dangerous settings where they have to learn how to react in an appropriate manner.

Fig 4.1 U.S. Navy personnel using a VR parachute trainer

4.5.2. In medicine: Staff can use virtual environments to train in everything from surgical procedures to diagnosing a patient. Surgeons have used virtual reality technology to not only train and educate, but also to perform surgery remotely by using robotic devices.

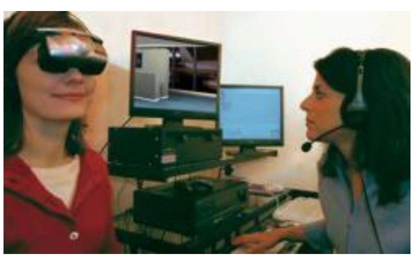

Fig 4.2 Using virtual therapy to treat a patient's

Fig 4.3 Endoscopic surgery trainer

4.5.3. Psychological therapy: Dr.Larry Hodges of the Georgia Institute of Technology use of virtual environments in treating people with phobias and other psychological conditions. They use virtual environments as a form of exposure therapy, where a patient is exposed under controlled conditions to stimuli that cause him distress. The application has two big advantages over real exposure therapy: it is much more convenient and patients were more willing to try the therapy because they know it isn't the real world.

4.5.4. In car companies: Car companies have used VR technology to build virtual prototypes of new vehicles, testing them thoroughly before producing a single physical part. Designers can make alterations without having to scrap the entire model, as they often would with physical ones. The development process becomes more efficient and less expensive as a result.

4.5.5. In gaming: The gaming industry has helped develop graphics and sound technology that can be incorporated as VR. There is an existence of entirely separate virtual worlds, inhabited entirely by the avatars of real world users. These worlds were sometimes referred to as massively multiplayer online games, and the World of War craft is the largest virtual gaming world in use now

Fig 4.4 Globe Theater

Chapter 5
Requirements and Project Protocol
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5.1 Hardware Requirements

1) VR Work station
2) Mouse
3) Monitor screen
4) Keyboard

5.2 Software Requirement

1) PEBL (TOL)
2) World Viz
3) Autodesk
4) SPSS(Correlation)

5.3 Paper and Pen Test Requirement

1) Consent Form
3) Rule Shift Card

5.4 Project Protocol

Healthy subjects of two groups were taken who differ in age group and each of one group perform same task. The subjects were educated male/female which sit in front of VR work station (VRM) and executive function test (TOL, Rule Shift Cart) after some full fill requirement of experiment in which subjects has to fill consent form. In the present study our aim was to measure executive function ability like, developing initiatives, making appropriate decisions, working memory, prioritizing, paying attention, focusing on important details, working toward a goal, shifting (to the next steps of a task or to the next task), stopping a finished action from the recorded data between graduate student and working employees.

- Total subject-30 (into graduate students group)
- Age Group-(20-25)
- Total subjects -10(into working employees group)
- Age Group-(30-40)

- Graduate students group testing (Same Criteria for working employees testing)
    - TOL from PEBL
    - Rule shift card
    - For VR
        - Learning phase with selective product
        - VRM (virtual reality mall) environment
- Data were recorded during testing.

The criteria for graduate students and working employees experiment were same.

5.4 Hardware Description

The description of various hardware required to carry out the experiment were as following:

5.4.1 VR Work Station

To assess executive ability, VRM was developed. The VRM, a 3D virtual environment, is designed to run on a computer with 4 GB RAM and a 2-GB compatible graphics card and i5 processor. Subjects navigate and interact within the VRM using the mouse. The user interacts with the VE using the keyboard arrows and a mouse to make selections [Figure 5.1].

Tasks include

• Navigating through a virtual reality mall by following specified routes through the rack.
• Finding and selecting items that is shown in learning phase.
• Pricing and selecting items so that no more than a budgeted amount is spent.

Fig 5.1 VR Work Station

5.4.2 Mouse

It is a device used for computer input. Computer mouse helps to navigate through graphical interface applications. It points and click on item, which is present in racks of shop .when cursor of the mouse point on items then name of items and prices is to be generated upon that items. If subjects want to purchase particular item which see in learning phase than press left button of the mouse. And if subjects want to move first floor through stair than press right button of the mouse.

Figure 5.2 Mouse

5.4.3 Keyboard

A keyboard is the set of typewriter-like keys that enables you to enter data into a computer. Here the main function of keyboard is to enter inside the virtual reality mall (VRM) by using up arrow of keyboard.

Figure 5.3 Keyboard

5.4.4 Monitor Screen

Here experimental take monitor screen of 13.3″ diagonal LED-backlit HD 16:9 widescreen Bright View (1366 x 768).The subjects is seated in front of the monitor screen with a practice TOL trial on screen.

Figure 5.4 Monitor Screen

5.6 Description of Software

The description of various software required to carry out the experiment as follows;

5.6.1 PEBL 0.12 Psychological Test Battery Software

Psychology Experiment Building Language (PEBL) is an open source software program that allows researchers to design and run psychological experiments. It runs on PCs using various operating systems (like Windows, OSX and Linux). It is first released in 2003. The tests were designed to implement a wide range of computer-administered psychological tests and experiments of interest to neuropsychological, cognitive, clinical communities. PEBL includes a set of more than 50 common psychological testing paradigms as part of its Test Battery.

5.6.1.2 Tower of London (TOL)

The Tower of London test is a well-known test used in applied clinical neuropsychology for the assessment of executive functioning. It is related to the classic problem-solving puzzle known as the Tower of Hanoi. Instructions were given to move the colored disks on the bottom set of three pegs to exactly match the positions of those on the first set. The need to preplan before beginning to move the actual disks is emphasized. When satisfied the final state of the disks matched the goal state, subjects selected a box marked ``accept’ ’ to move on to the next trial. The computer recorded for each trial: preplan times (from appearance of disks to first movement with light pen), total no of attempts and no of trials solved [26].

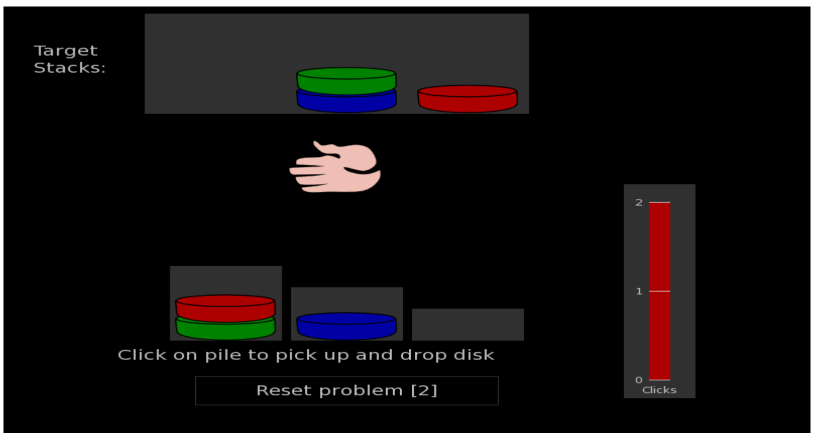

Figure 5.5 TOL test from PEBL

5.6.2 Auto desk

Autodesk, Inc. is an American multinational software corporation that focuses on 3D design software for use in the architecture, engineering, construction, manufacturing, media and entertainment industries. During design of VRM using world viz, Vizard was not found compatible with large number of 3-D format, *e.g.*,

max, wrl, to add in this environment. It was needed, because availability of some 3D format was not in another format. So, auto desk conversion of that format can easily convert **max, wrl** 3D format in to **obj or 3ds** format. In this way by converting format was easily compatible with vizard and it had been possible to create interactive VRM.

5.6.3 Worldviz

VR applications provide appropriate methodological, technological, software and data collection training to use state-of-the-art immersive virtual environment technology to construct complex interactive simulations. There is no formal requirement for a computer programming. If subjects have basic knowledge he/she can program. Python programming have built in intelligent code and interactive simulation engine.

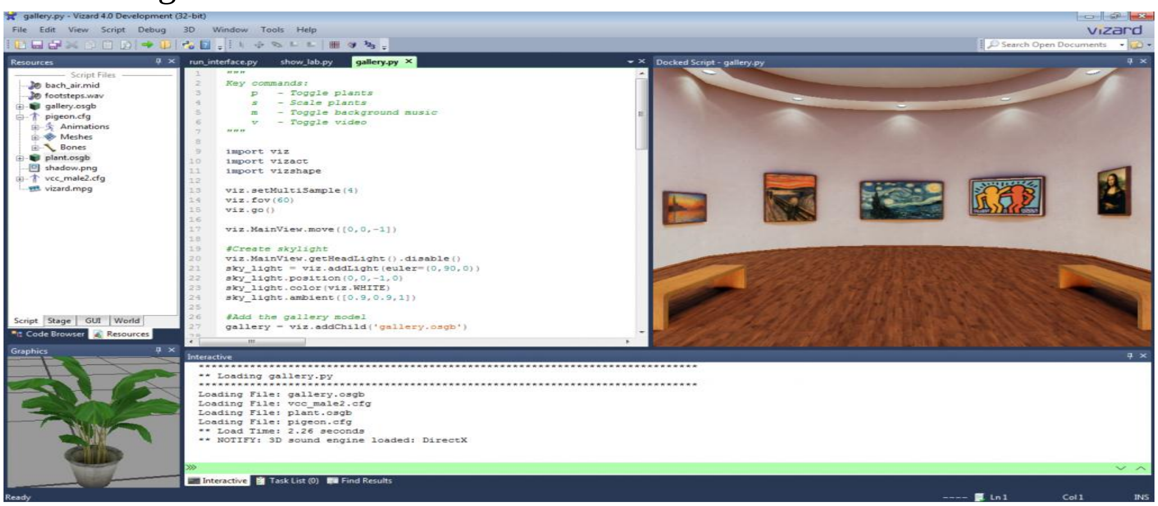

Figure 5.6 Showing the Integrated Worldviz platform

To design VE tasks python was used as a programming language, it is a scripting language.

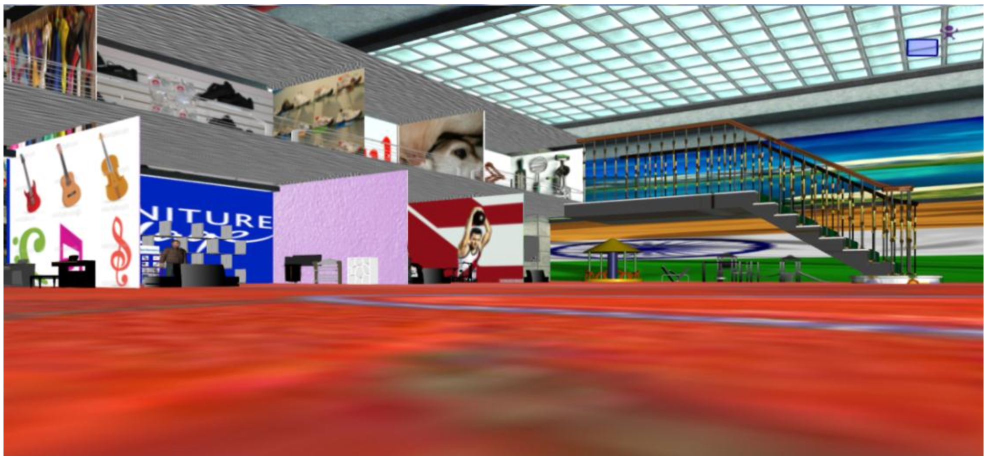

Figure 5.7 Virtual Reality Mall

5.6.5 Statistical Product and Service Solutions (SPSS)

SPSS Statistics is a software package used for statistical analysis. SPSS Statistics (originally, Statistical Package for the Social Sciences, later modified to read Statistical Product and Service Solutions) is released in its first version in 1968.SPSS is among the most widely used programs for statistical analysis in social science. It is used by market researchers, health researchers, survey companies, government, education researchers, marketing organizations and others .In addition to statistical analysis, data management (case selection, file reshaping, creating derived data) and data documentation (a metadata dictionary is stored in the data file) were features of the base software. SPSS is released in its second version in 1972.

5.6.5.1 Bivariate statistics

It is one of the simplest forms of the quantitative (statistical) analysis. It involves the analysis of two variables (often denoted as X, Y), for the purpose of determining the empirical relationship between them. In order to see if the variables are related to one another, it is common to measure how those two variables simultaneously change together.

SPSS Statistics can read and write data from ASCII text files (including hierarchical files), other statistics packages, spreadsheets and databases. Statistical output is to a proprietary file format (*.spv file, supporting pivot tables) . The proprietary output can be exported to text or Microsoft Word, PDF, Excel, and other formats.

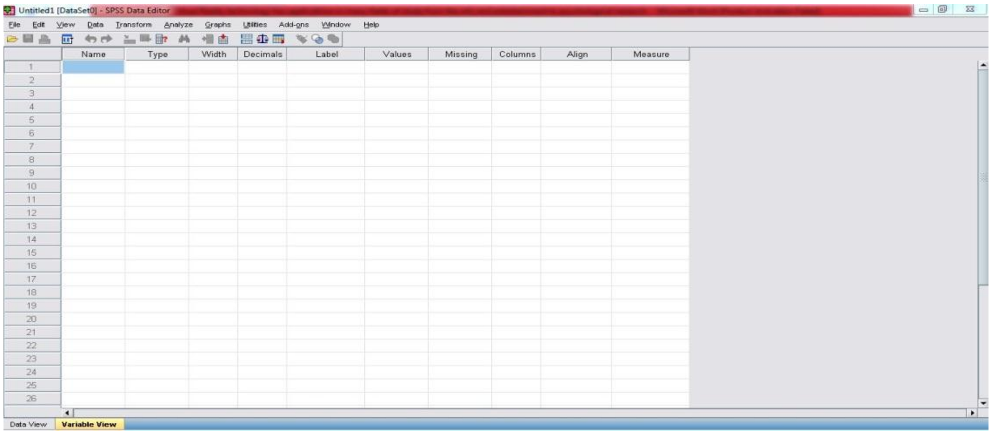

Figure 5.8 Descriptions of SPSS

5.7 Description of paper and pencil test

5.7.1 Rule Shift Card

This measure uses 21 non picture playing cards and it assesses the ability to change from one pattern of responding to another. In the first part of the test, subjects were instructed to answer “Yes” to a red card.

Fig 5.9 Red Card

and “No” to a black card.

Fig 5.10 Black Card

In the second part, subjects were instructed to respond “Yes” if the card which has just been turned over is the same color as the previous turned card.

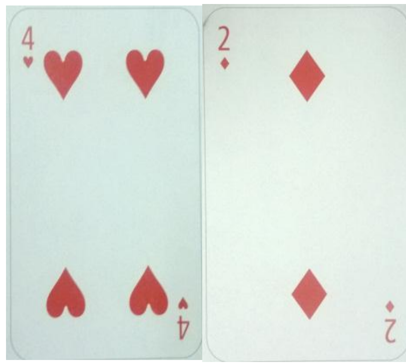

Fig 5.11 Same Color Card

and “No” if the color is different.

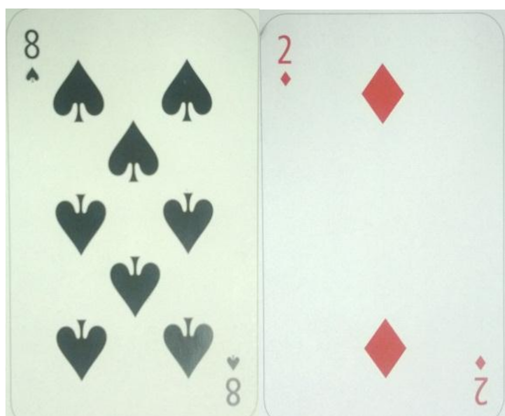

Fig 5.12 Different Color Card

These rules, typed on a card, were left in full view throughout to reduce memory constraints. Time taken and number of errors were recorded in both parts. This test assesses flexibility and inhibition abilities, as well as rule learning. This measure uses 21 non picture playing cards and it assesses the ability to change from one pattern of responding to another. In the first part of the test, subjects were instructed to answer “Yes” to a red card and “No” to a black card. In the second part, subjects were instructed to respond “Yes” if the card which has just been turned over is the same color as the previous turned card and “No” if the color is different. These rules, typed on a card, were left in full view throughout to reduce memory constraints. Time taken and number of errors were recorded in both parts. This test assesses flexibility and inhibition abilities, as well as rule learning [27].

Chapter-6
Experiment Set-Up and Methodology

This chapter includes the experimental set-up and methodologies to compute the result.

6.1 Experiment Set-Up

The whole experimental set up includes the following

- Executive function data recorded :VRM,TOL, Rule shift card
- Psychological test battery : PEBL executive function test battery software
- Virtual environment (learning Phase)
- Virtual reality mall (Training Phase)
- Rule shift card

The recording of data having the same criteria for two groups

- Rule shift card
- Tower of London
- Show learning phase-35 sec
- Virtual reality mall (VRM)

Total experiment duration is approx. 30 Minutes

6.2 Methodology

This part of a thesis includes procedures and approaches by which we can get results and can analyze them. After acquiring data, the processing of these data will be done using SPSS (Statistical Package for the Social Sciences) technique. The complete procedure and techniques were as follows:

6.2.1 Steps to analyze the data:

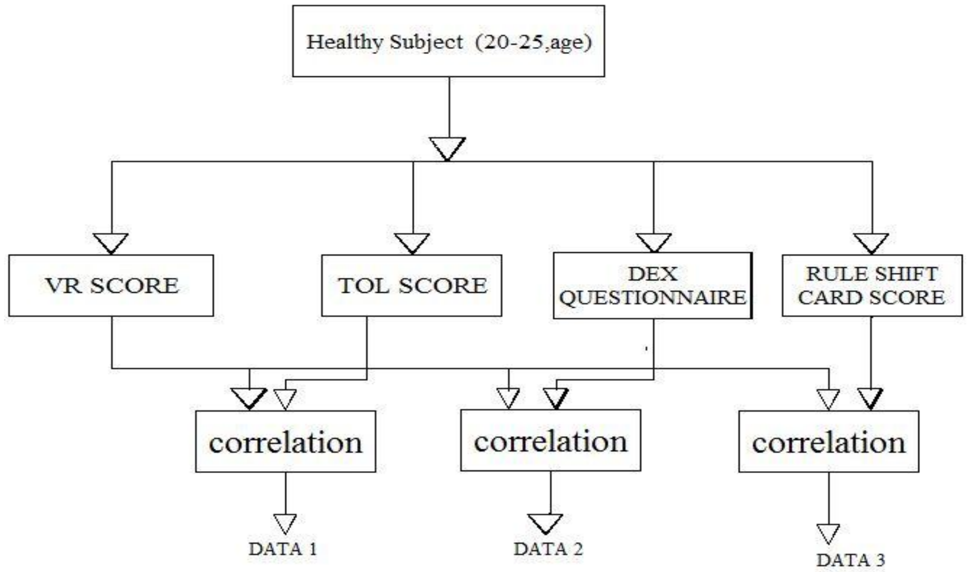

Figure 6.1Steps of analyze the data

6.2.2 Subjects

Thirty undergraduate subjects (16 females, 14 males; Age =20-25 years) and ten working employees (2 females, 8 male; Age=30-40) were recruited.

6.2.3 Measure

After providing informed written information consent, all subjects completed executive function test (TOL, rule shift card) and VRM. The time required for testing is approximately 30 min per subjects. A brief description of the standardized tests and VRM is shown below.

6.2.4 Learning phase:

Fig 6.2 Learning phase

Researcher show virtual environment (learning module-35 sec) before go to virtual reality mall. Which consists of seven items of product [Fig. 6.3].subjects has to learn this item with very alertness and purchase. Each item has its own cost .all the information related to VRM is given before learning phase. Means researcher tell subjects that you have ‘1000’ rupees .and you have to purchase all seven item with in ‘1000’ rupees. Correct and incorrect action taken by subjects describe below. This is noted by Researcher on note book.

(a) Product 1

(b)Product 2

(c) Product 3

(d) Product 4

(e) Product 5

(f) Product 6

(g) Product 7

Fig 6.3 Seven product list (a-g)

6.2.5 VRM

Operation of the VRM includes a series of actions, described as a task, and allows an analysis of the strategic choices made by clients and thus their capacity to plan, such as the "test of shopping item". The VRM simulates a fully textured, mall with multiple racks displaying most of the items that can be found in a real supermarket. Before enter in the virtual reality mall (VRM) subjects has to fill some information [14].

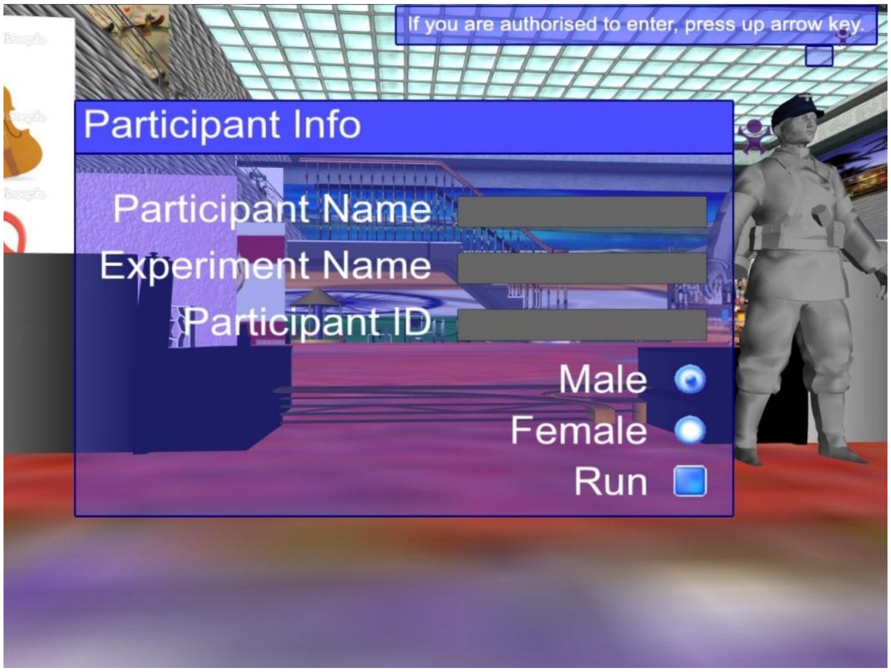

Fig 6.4 Information set up regarding VRM

There were also three check-in counters; three cashiers, an exit counter and a shopping cart, as illustrated in [Fig 6.5].

Fig 6.5 VRM entry point

Some indication, like name of the rack or cartons, is used for interactive purpose. The test task is to purchase seven items from a clearly defined list of products and then proceed to the cashier's desk and to pay for them. List of seven items is shown in learning phase [Fig.6.3]. Twelve correct actions (*e.g.*, selecting the correct product) were required to completely succeed in the task. Actions were considered as incorrect if the client:

1. Chooses inefficient patterns of performance such as entering a shop but not performing the required task within the shop
2. Chooses same item twice or
3. Taking inefficient routes around the mall to complete task requirements or
4. Entering the same shop on two separate occasions to perform two tasks that could have been performed in a single visit

A training task which is similar but not identical, test was also available to enable the user to get acquainted with the VE and the tools. The task-related instructions at first were given by the researcher which items displayed on the screen of learning phase. As the subject's progresses with the purchases, the items appear in the cart and disappear from the rack [Fig 6.6].

Fig 6.6 product disappear after purchase

The cashier-related instructions were verbal and given in the beginning of the session. While sitting in front of a PC screen, the subjects enter the mall by using up arrow of the keyboard. He had to choose the cart as if he is pushing it, and move around freely by pressing the left button of mouse. If the subjects want to go upstairs, then the right button of mouse had pressed. He was able to experience the environment from a first person perspective without any intermediating avatar. The subject is able to select items by pressing the left mouse button. If the item selected is one of the items on the list it will transfer to the cart. After completing the task, subjects may take the items from shopping cart at the cashier check-out counter or leave the shopping cart and pay bill by using left button of mouse. After that he/she has to proceed to the mall exit. The VRM (virtual reality mall) records various outcome measures (times, actions) while the subjects experiences the VE and executes the task. At least nine variables can be calculated from the recorded data: the total task time in seconds, select check point or not, the number of items purchased, the number of correct actions, the number of incorrect actions, the number of pauses, and the time to pay, VR score, balance left, cart before and after purchasing select or not, pay cash and exit or not. All the information is recorded in a document file, except the time to pay, which is recorded by using timer. In this way subjects were always under supervision of the researcher [14].

6.2.5.1 VRM Analysis

The test task is to purchase seven items from a clearly defined list of products.in this way each correct and incorrect action had one point to perform task. But condition to calculate some other point of VRM calculated in different manner. Means if subjects perform its task with in average time than researcher will give only one point otherwise zero. And same point distribution was done in total no of pauses but with negative sign .if at end of the task subjects had balance range from - 40 to 60 than give one point otherwise zero.

Chapter 7
Results and Discussion

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7.1 Results

7.1.1 Test Performance Analysis

Table I - II shows tests performance of graduate student and working employees on the VRM and executive function test. In both cases standard deviation of all the parameters were found better for graduate students. Researcher observed that in VRM, 56% correct action (7/7) was performed by the graduate students whereas actions of working employees were only 30% successful. Not choosing the shopping cart before purchasing the list of item or not leaving it at cashier counter was noted to be 1.6% in the case of graduate students while it was 10% for the working employees. Total time to complete task performed by the graduate students (56%) was with in average total time compared to working employees (10%). Again, time to pay was better performed by the graduate students (63%) compare to working employees (20%) [23], in this way, the balance left was more with the graduate students. Fig. 7.1 shows that VR score of graduate student was better than the working employees. This may be due to the slower reaction. They analyze the environment for a long time and didn't make impulsive decisions or underestimate the importance of VRM task and/or overestimate with their own abilities. And thus did not put sufficient effort into this aspect of task performance [23].which can also be seen with the help of the graph in figure [7.1]. In order to be successful on the VRM, subjects had to plan efficiently, monitor their actions and prioritize competing tasks.

Table I. Test Performance of Graduate Students Group

S.N.		Mean	Standard Deviation
A	**VRM**		
i.	Total time to task	413.13	99.21
ii.	VR Score	10.6	4.43
iii.	Time to pay	68.93	25.76
iv.	Incorrect action	1.25	0.26
v.	Correct action	6.3	1.5
vi.	Total balance left	67.5	199
B	Executive Function Tests		
	TOL		
i.	Total no of attempts	21.1	3.06
ii.	No of trail solved	10.66	2.28
iii.	TOL score	26.92	3.91
	Rule shift card		
i.	Profile score	3.06	0.68

Table II. Test performance of working employees

S.N.		**Mean**	**Standard Deviation**
A	**VRM**		
i.	Total time to task	536.1	163
ii.	VR Score	7.6	2.89
iii.	Time to pay	88.7	37.60
iv.	Incorrect action	1.28	0.28
v.	Correct action	5.6	1.4
vi.	Total balance left	29	64.14
B	**Executive Function Tests:**		
	TOL		
i.	Total no of attempts	20.9	2.58
ii.	No of trail solved	10.2	0.33
iii.	TOL score	24.2	3.56
	Rule shift card		
i.	Profile Score	2.3	0.7

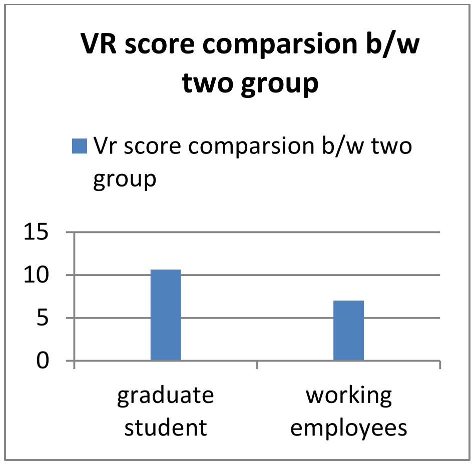

Figure 7.1 VR score graph b/w two group

7.2 Correlation Analysis

7.2.1 VRM variables

VRM is a good training module than traditional neuropsychological paper pencil tests to assess executive functioning [12]. In the study the variation in the data is statistically analysis by using Statistical Package for Social Sciences (SPSS) for Windows, version 16.0. In SPSS correlation of various types of test data is performed using bivariate relationship. Pearson correlation coefficients were computed to examine the relationships between the various scores of the VRM with executive function test and between the VRM (Table III).

Table III. Correlation of VRM in graduate students

VRM	VR Score	Correct action	Task time	Pay time	Incorrect action
VR Score		0.745*	-0.552*	-0.330	0.568
Correct action			-0.239	-0.048	0.714*
Task time				0.411*	0.788*
Pay time					0.442

Abbreviations: VRM, virtual reality mall; if *p < .05; **p < .01 than (r=significant)

The VR score measure was negatively associated with the total time to complete task, such that higher the VR score take less total time to complete task (r = -0.552, p = 0.01). Longer total time to complete task were positively associated with a higher number of incorrect action (r = 0.788, p = 0.01) it means that incorrect action rate of the graduate students were less compared to working employees and the VR score measure were positively associated with the total number of correct action, such that the higher the VR score, more are the correct action (r = 0.745, p = .01).Also, the correct action was negatively associated with the incorrect action, such that the higher the correct action will be, lesser are the incorrect action (r = -0.714, p = .01). VRM variable analysis of both group shows that maximum numbers of graduate students were comfortable with VRM to obtain good score in all variable. When compare with working employees using stastical analysis.

Table IV. Correlation of VRM and executive function test in graduate student

VRM →	VR Score	Correct action	Incorrect action	Task time	Pay time
Executive function test:					
1. TOL					
Total time of attempt	-0.141	-0.439	-0.132	0.270	-0.019
No of trail solved	0.157	0.612	0.247	0.074	0.047
Tol score	0.178 *	0.490	0.147	0.180	-0.036
2.Rule shift card					
Profile score	0.143	0.143	0.240	-0.295*	-0.047

7.2.2 Relation of VRM variables with executive function variable test of graduate student

Table-IV shows the correlation between various variable of VRM and executive function test in which two correlations were significant. i.e., performance on the rule shift card (profile score) were negatively associated with total task time of VRM (r = -0.295, p = 0.05), such that the higher profile score of rule shift card will take less total time to complete task. Another correlation was positively related (r = 0.178, p = 0.05), which shows that those graduate student had obtain better tower of London score who was comfortable to obtain highest VR score .This can also be conveyed through the figure [7.2-7.3], in which maximum number of peaks show that maximum graduate student who had obtained good TOL score, were also capable of obtaining good VR score. But some peak show poor performance of graduate students. But the overall performances of graduate students were better than the working employees. In this way VRM has been proved to be ecological valid using TOL to asses executive function to good extent. A separate analysis of other variable of VRM with executive function test revealed that no correlation were significant (i.e., TOL or rule shift card with VRM).

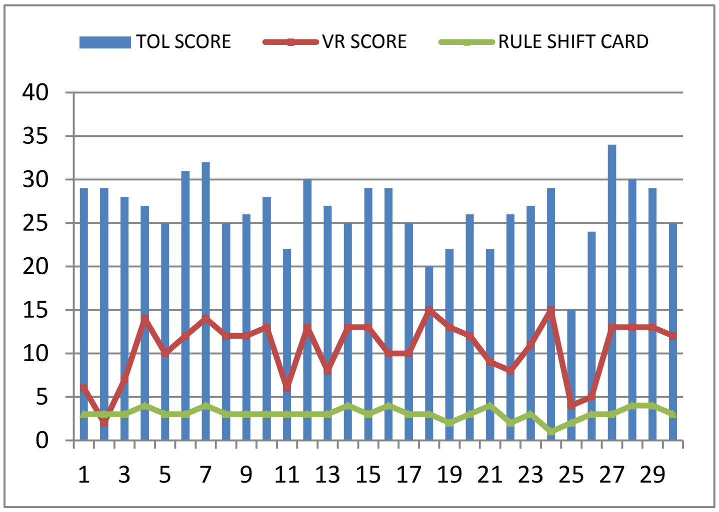

Fig 7.2 Graduate Student score of executive function test and VRM

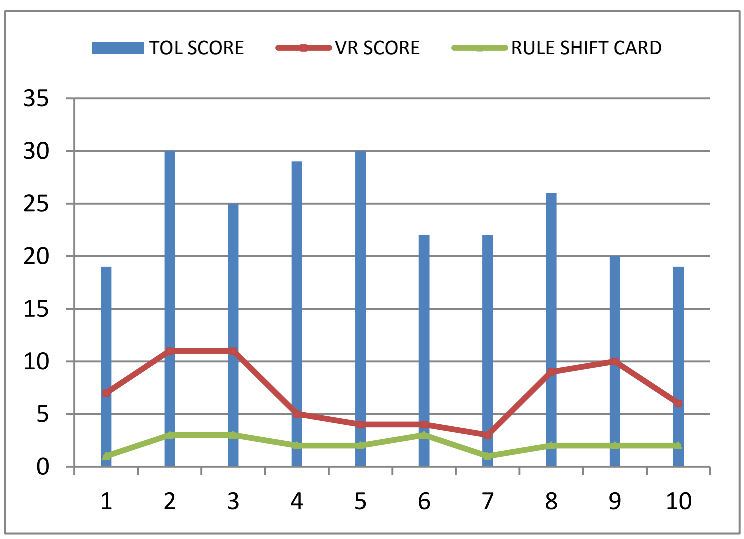

Fig 7.3 Working Employees score graph of executive function test and VRM

Table V. Correlation of VRM in working employees

VRM	VR Score	Correct action	Task time	Pay time	Incorrect action
VR Score		0.665*	-0.166	-0.426	-0.750*
Correct action			-0.360	-0.258	-0.439
Task time				0.305	-0.490
Pay time					0.238

7.2.3 VRM variables analysis of working employees

Various variable of VRM correlate with in various variable of VRM for the working employees and researcher found less significant correlation compare to the graduate students. Pearson correlations were computed to examine the relationships amongst the various VRM measures (Table V). The incorrect action measure is negatively associated with VR score, i.e., higher the incorrect action done by the subject will not perform better VR score (r = -0.750, p = .05). Here VR score were positively associated with a correct action (r = 0.655, p =.01). Only two value of correlation found significant for $p<0.05$ or $p<0.01$ compare to the working employees**.** The VRM test analysis that the majority of subjects did not see any memory relation related to product on screen (i.e., calculating how much money they would have left over to purchase item). A few subjects did run out of money, however, because they repeated purchases (e.g., buying item more than once).

Table VI. Correlation of VRM and executive function test in working employees

VRM ⟶	VR Score	Correct action	Incorrect action	Task time	Pay time
Executive function test					
1. TOL					
Total time of attempt	-0.387	0 .274	-0.302	0.353	0.246
No of trail solved	-0.047	0.767	0.161	0.007	-0.443
Tol score	0.091*	0.647	0.338	0.019	-0.187
2.Rule shift card					
Profile score	0.44	-0.439	0.169	-0.348	0.264

7.2.4 Relation of VRM variables with executive function variable test of working employees

Table-VI explored the correlation between various variable of VRM and executive function test in which one correlation was significant. That is the performance on Tower of London score is positively associated with VRM score (r = 0.091, p = .05). In this way researcher again find that VRM has ecological validity with TOL to find executive function at some extent see figure [7.3]. This graph shows that four out of ten peaks of VR score had good response with tower of London score. But rest of peaks of VR score had not good response with tower of London score. This may be due to large number of variable taken of VRM and have more rule and regulation as compare to executive function test.

7.2 Discussion

A novel VR test of executive function, the VRM, was administered to a normal group with the objective of exploring executive functioning ability. This study set out to ecological validity of VRM with TOL and also shows that graduate students had better score in compression to working employees.

The result of VRM prove that desktop virtual reality has more alertness activity .in which all executive function ability can be recorded.it offer assessment and manipulation option that are not available using traditional assessment method

7.4. Some Common Mistakes

- A few subjects run out of money, however, because they repeated purchases (e.g., buying product more than once).
- The majority of subjects did not see any information related to product purchase on screen (i.e., not calculating how much money they would have left over to purchase item).
- Other common mistake involved inefficient patterns of performance such as entering a shop but not performing the required task within the shop.
- Entering the same shop on two separate occasions to perform two tasks that could be performed in a single visit.
- Entering unnecessary buildings and waste time.
- Taking inefficient routes around the mall to complete task requirements.

Chapter: 8

Conclusion and Future Scope

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8.1 Conclusions

Results conclude that the VR works better for graduate students than for working employees. This may be due to the fact that students due to having to memorize subject matter may find it easier in this task then people out of touch with memorizing. Given the above mentioned results, it is possible to conclude that the VRM appeared sensible to check executive function ability like Tower of London using design task. As an assessment tool, VRM should be analyzed with regard to its temporal stability, before being ready for clinical. This study provides preliminary data supporting the ecological and constructs validity of the VRM as an assessment tool of executive functions and its role in differentiating between graduate students and working employees with different age groups, with regard to the healthy population.

8.2 Future Consideration

There were several key issues that need to be addressed more and more as VEs expand from being primarily supportive of single user, local location applications towards accommodating multiple users in local and remote locations.

- The model can be used for making improvements upon people with dementias memorizing skills.
- We can test this model upon larger number of test subjects.
- We can work on improving this to help with people suffering from Alzheimer and Parkinson disease
- Can be used for design virtual infrastructure.

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