Analyzing Art, Culture, and Design in the Digital Age

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Chapter 10
New Ways of Seeing:
Evaluating Interactive User Experiences in Virtual Art Galleries

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ABSTRACT

As computer-driven display technology becomes more powerful and accessible, the online, virtual art gallery may provide a new platform for artists to exhibit their work. Virtual exhibits may afford opportunities for both the artist and the patron to display, view and perhaps purchase various digital art forms. The aim of this paper is to examine user interaction with digital artworks inside a virtual gallery space. We use a range of criteria to describe conditions for both the designer and the user of such a virtual display system. The paper describes a number of experiments where users interacted with a virtual art gallery and were then extensively interviewed and surveyed. Measures of what Manovich (2002) describes as 'immersion' and what Slater et al (1994) would term 'presence' are observed in relation to the user experience. The gallery is a three-dimensional graphic digital construction built in Second Life. The experiment aimed to describe and delineate the user's perception and navigation of space and compares their perception of art objects in the virtual environment to digital objects in a 'real world' gallery. The data collected in this study provide the basis for a discussion of how users may perceive and navigate virtual objects and spaces in an online environment such as a game or art gallery. The results may be of use to those designing interactive three-dimensional environments.

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INTRODUCTION

Over the centuries, visual artistic expression has captured emotion and affected human perception. This has led to the development of scientific principles of vision and color which began with studies of color in the 14th century, and continued with research into use of optics in art in the 15th century. Scientific understanding of fabrication and the assembly-line led to the mass-reproduction of colored objects during the industrial revolution. Advances in technology and physics sparked new forms of art such as impressionism and neo-impressionism. Artists such as Van Gogh (1853-1890) and Paul Signac (1863-1935) used modern concepts of color and vision to express more abstact views of life and nature. In the twentieth century modernist movement, the paradigm of political, mythological and spirtual abstraction in art became meshed with the power of the imagination. The meaning of art was recognized as one that is shared between the viewer and the artist (Douma, 2006).

In the 1960's digital processing allowed for the computer mediation of human imagination and the creation of computer-generated visual art. The first Graphical User Interface (GUI) was created by the Xerox corporation in the 1970's. During the 1980's digital art evolved as artists began to create artwork using computer software. This practice would conceptually change the significance of the art itself, as microchips and processors were now processing the artwork. As Kuspit (2005) states: "Essentially, the digital artwork becomes a second manifestation... of the abstract code, which becomes the primary vehicle for creativity."

Humans have traditionally used their physical senses in proximity to the painting, drawing or sculpture to produce the visual-haptic-gestural feedback that allows them to experience the work of art. These days, artists present and distribute their work in many new ways using online virtual spaces. They are now able to reproduce, rescale and reproduce their artwork digitally. The viewer or purchaser of such art also operates in a virtual environment to access the art and perhaps download it and create their own copy. There may be cultural and social advantages to replicating and disseminating artwork over the Internet. No longer are paintings secluded in museums and prestigious art galleries which are often the domain of the educated classes. With the advent of digital simulations and computer driven technology, artists may create new forms of interaction with the audience.

In this study, participants experienced works of art using diverse display technologies including real and virtual environments. Participants compared their perception of art displayed within a virtual gallery environment to art viewed directly on a computer screen (using PowerPoint). We interviewed participants to examine their responses to the various display systems.

This research asks what happens to this feedback when the artwork is reproduced or displayed in a three-dimensional virtual environment? How doe this viewing environment effect the physical sensation of viewing an artwork? What effect may the use of totally virtual reproduction have on the precision and scale of an artwork? Can these dimensions be manipulated differently than an artist could manage in real life?

The use of three-dimensional graphic tools for displaying visual art is evolving as an art form in itself. Virtual environments allow users to immerse themselves and engage in expression and creativity. Such new forms of digital media may ultimately traverse traditional ideas of visual communication and lead to new and diverse models of conceptual artwork (Popper, 2007).

This study focuses particularly on the three-dimensional graphic (3D) environment allowed by shared online spaces. Second life (www.secondlife.com) is a Massive Multi-player Online (MMO) 3D graphic environment that was launched in 2003. The software is downloaded to the user's computer connecting

it to a global bank of servers in a vast matrix of online locations and spaces. As a 'resident' of this online world, the user creates their own avatar, a graphical version of themselves who moves around within the onscreen world. Residents are able to explore the Second Life world, meet other residents, travel to destinations by flying, walking, or teleporting; participate in social activities and learning environments; create and trade goods and services; own and create property, and access media (Figure 1). With ever growing content, there is an immense amount of artistic experimentation and artwork generation and display (Dethridge, 2009; Malaby, 2009).

In recent decades, computer users have viewed the virtual environment through a laptop or desktop screen, but technology is allowing users to immerse themselves into gaming worlds with larger screens, three-dimensional displays and Head Mounted Display (HMD) units at lower costs than ever before. Also we are seeing a move towards handheld mobile devices (most with limited screen real estate) becoming a pervasive medium for interaction with a range of media experiences. The use of such a wide range of interface metaphors means that the viewers who are interacting with any virtual art work will have varying experiences, mediated by the technology being used.

INTERACTION METAPHORS

Studying how humans have interacted with art for the past thousands of years provides a framework to explore how multiple components (including visualization, embedded cognition and human-computer interaction) may work together when considering art displayed in virtual galleries. This paper will consider a number of questions including:

- Is immersion necessary for viewing paintings in a virtual environment?
- Is a well-designed user interface important for enjoying a painting?
- Does the graphical power and resolution of the display play a role?

When a user engages with artwork through a virtual portal such Second Life, the software interface may effect how they interact with and conceptualize the work. This visual experience is a function of several human processes; human visual behavior, embodied cognition and human computer interaction. Each of these components will alter the users experience with varying degrees. Analysing the variables associated with each of these components extends our understanding of how a user defines their inter-

Figure 1. Views from Second Life (www.second life.com).

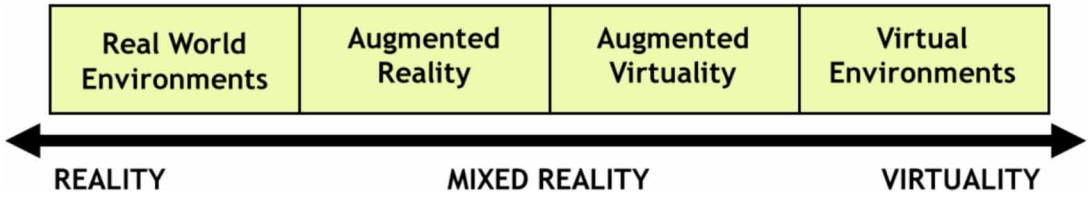
action and engagement with a particular virtual artwork. The Virtual Reality (VR) continuum (Figure 2) describes an object being viewed by defining the display mechanism being used to view the object (Milgram and Kishino, 1994).

- On the left side of the continuum, there are real environments, for instance, a real museum full of paintings and sculptures (Tate, Loovre, MOMA etc.).
- Next is Augmented Reality (AR), which refers to physical spaces which are integrated with virtual technologies. For example, imagine walking through a museum using a video camcorder to record the experience. The viewer is looking at actual paintings, but mediating the experience through a digital screen. Other extra (augmented, non-diegetic) visual information may be present on the screen display such as; time, display resolution, zoom depth, or framing alignment bars.
- Alongside augmented reality is Augmented Virtuality (AV) which refers to virtual spaces that are integrated within the physical world; for example, viewing a live podcast on a virtual screen within the Second Life virtual environment.
- And finally, Virtual Environments (VEs) refer to entire simulated computer environments that stimulate the user through a combination of sensory information (such as most computer games). Even this category may by further divided based on the display mechanisms used:
    - Virtual Environments (such as games played on a standard LCD screen or computer monitor) and
    - Immersive Environments that use more advanced interaction technologies, such as Head Mounted Displays (HMDs) or Cave Automated Virtual Environments (CAVEs).

Other taxonomies that are used to categorize a virtual experience include:

- Sheridan (1992) measured "presence" using three factors: extent of sensory information, control of relation of sensors into the environment and ability to modify the physical environment. Difficulty of the task was also sometimes used to classify presence.
- Zeltzer (1992) classified graphic simulation systems by: components autonomy, interaction and presence. This scheme is widely used in the literature for classifying virtual environments.
- Naimark (1991) classified several ways in which a user can record and reproduce a visual experience, including: monoscopic (two-dimensional), stereoscopic (three-dimensional), multiscopic (viewing multiple angles at once), panoramic (wide angle view), surrogate travel (remotely controlling a robot) and real time (such as Magnetic Resonance Imaging).

Figure 2. The Virtual Reality Continuum (adapted from Milgram and Kishino, 1994)



- Robinett (1992) classified different technological devices for simulation and interaction ranging from head mounted displays to microscopes and telephones. The taxonomy consists of classifying devices by nine components (encompassing causality, model source, time, space, superposition, display type, sensor type, action measurement type and actuator type).

While relying on previous research undertaken in the field, the work presented in this paper gives new insights into the viewing of art in virtual environments. Specifically, this paper describes a series of experiments that examine and compare three attributes of human behavior which are demed important when viewing virtual art gallery environments.

- Human Vision: Based on an understanding of how users visualize and conceive color and light.
- Embodied Cognition: Based on an objective definition of 'immersion' (diminished awareness of self) and measuring the effects of user 'presence' as they interact with a three-dimensional virtual environment.
- Human Computer Interaction: Users of the virtual environment will examine art work in virtual galleries. Awareness and involvement should be suggested with avatar movement and time spent engaging with the art work.

The intrinsic characteristic of 'engagement' is often seen as a useful metric for evaluating the user experience within a virtual environment (Walsh, 2009). This will be considered as the users will interact with the artworks across a range of displays, positioned at different points along the VR continuum (Milgram and Kishino, 1994) including: Augmented Reality (digital paintings) and Virtual Environments (Second Life viewed on a screen) and Immersive Environments (Second life viewed through a HMD).

Attribute 1: Visual Analysis

Human vision is a function of an operation where we use our senses and brain to input and compile real world data in order to determine the nature of objects, including shape, material and roughness. Our perceptions will vary with experience and age. The physiological and cognitive processes that resolve our visual input also calculate the level of precision used to perceive a specific real world object. How the object appears to us is also directly influenced by the illumination and the shape of the object (Vangorp, 2009).

Human vision may be described as the perception of physical objects and conditions which may be perceived to be three-dimensional objects built up from the patterns of light that project onto the retina. Whereas objects in the real world, such as a sculpture, exist in a three-dimensional space and have atomic properties, the human viewer generates their individual image of that sculpture on an internal, personal, two-dimensional projection screen (Todd, 2004).

While it is not possible to measure direct perceptual quantities, the user's perception of the properties can be observed and measured. It is important when quantifying an individual's experience of observing a visual artwork such as a painting, to note that color is not a construct of pure light frequencies. Color is a function from spectral reflectance that is constructed in the brain. Because of this complex processing, how any work of art appears to an individual is a combination of the features of the work itself, the display mechanism and of the viewer's perception. Hence, the visual perception of a virtual artwork will ultimately be influenced by both the display medium and the user's perception.

Attribute 2: Immersion

Virtual Environments (in particular HMD technology) provide a unique opportunity for users to surround themselves visually with virtual and imaginary spaces. This experience has driven many experts to attempt to define the phenomenon that Ivan Sutherland calls 'being there'. The common terms today are 'presence', which is an abbreviation of Telepresence suggested by Minksy (1980) and 'immersion', suggested by Murray (1997).

While there is a vague, general consensus on the nature of the phenomena itself, there tends to be a variance in the actual definitions. Oliver Grau (2004) applied the term immersion to paintings, whereas with multimedia and digital media, immersion is often used to describe the overall interactive experience (Grau, 2004; Mäyrä & Ermi, 2005; Schofield, 2011). There have been numerous and separate studies on immersion, presence, virtual environments and interface design. Many scholars continue to debate the definitions of presence and immersion (Slater et al, 1994; Manovich 2002), as well as its application and relevance within virtual environments and conceptual interface designs. Slater (2003) also suggests that presence is like form: "the extent to which the unification of simulated sensory data and perceptual processing produces a 'coherent' place that you are 'in' and in which there may be the potential for you to act".

Schubert et al (2008) provide a useful concept when considering the viewing of digital artwork, where both presence (a qualitative experience) and immersion (a quantitative experience) drive the development of many three-dimensional virtual art galleries. They state that:"When possibilities to act in a spatial environment are perceived or when dramatic events structure the interaction, presence emerges. Both spatial and dramatic conceptualization can be framed as meaning. Spatial and dramatic meaning determine how present we feel in a virtual environment". Embodied cognition describes how physical action is dependent on a human's cognitive processing. For instance, vision requires bodily movement and the feedback from this movement is processed in the brain. The essential thesis of embodied cognition theory is that the mind is connected to the body and influences it directly just as the environment influences both mind and body. This process is embedded in our physiology and also helps explain how metaphors become meaningful which correlates with the idea of immersion, creating an environment that allows an individual the ability to facilitate or augment their own sense of presence (Calleja, 2011).

For any user to experience a visual artwork, they must observe it first hand with their own eyes. Conflating the artwork, the environment and the user's mind may be likened to a visual, symbolic discourse that enhances the planes of the viewer's physical reality. How the user structures their interpretation of these elements is defined by the significant variables that affect the user's perception. By experimenting with, and monitoring, users observing artwork in fixed virtual and real environments; it is possible to identify key elements which link immersion and presence to the larger concept of experience.

Attribute 3: Human-Computer Interaction

In a three-dimensional environment, the entire world is essentially a visual metaphor created for the user to express an idea or emotion through affordances, visuals and sounds within the virtual world. It is hypothesized that the degree of interaction within the environment will affect the individual's sense of presence; and in turn his or her subjective sense of being in the virtual place (Schubert et al, 2008). In the research, immersion and presence are often viewed as functions of interaction, hence, it is important to understand the modalities and interface types in which the artwork is being viewed and experienced.

Typically, the Second Life virtual environment is viewed from a user's account on a desktop computer screen or laptop using a keyboard and mouse for input. Users create an avatar which allows them to (Dethridge, 2011): "experience vicarious vision, public visibility, physical motion and interactivity with other objects and entities in this world." The three-dimensional environment that the user controls is a function of the visual cues based on the avatar's onscreen proximity to objects. Essentially, the avatar is a pivot point for directing a virtual camera to interact with the three-dimensional world from a 1st person (egocentric) or 3rd person (exocentric) view (Byson, 1994; Bryce, & Rutter, 2002). This virtual camera perspective which allows the user to view of artworks within a three-dimensional environment is a (Dethridge, 2011): "space where the real and virtual image merge; where time, 3D animation and the avatar's enhanced perspective"

EXPERIMENTAL DESIGN

To examine the impact of these attributes on a user's experience in a virtual gallery, a number of experients were undertaken. These experiment required a group of participants to directly view works of art on a range of display technologies. The group also interacted with virtual art gallery environments thus experiencing a range of interaction across the spectrum of real and virtual environments and display conditions. Online virtual environments, such as the ones used in this experiment permit the scientific study of human behavioral responses in a controlled laboratory setting alongside ecologically valid contextual cues (Kim et al, 2012).

After viewing the art work, the participants were interviewed and filled out surveys about their experiences and reported on their feelings regarding the artwork. Each participant's viewing sessions was video recorded to allow the researchers to analyses the behavior of each participant in detail. The data collection was structured so as to allow the analysis of the three attributes of interest (visual content, immersion and interaction) and to measure how each of these affects the user experience.

The experiments were split into two distinct sections. The first part of the experiment required participants to view artworks on a computer screen in two distinct modes. The participants used a PowerPoint slide presentation to interact with digital images of four paintings; they also used the Second Life virtual environment to interact with the same four paintings displayed in a virtual gallery. The second part of the experiment collected data from users who viewed the same four paintings in Second Life wearing a SONY HMZ T1 HMD (Figure 3).

As display screen technology continues to advance, HMD units are becoming more accessible in terms of cost as well as comfort and universal connectivity to home devices. There has been a large amount of research undertaken on high-end uses of HMD technology. However very little work has been done based on the new, lower-cost end of the technology spectrum, examining everyday, consumer entertainment applications. A number of previous studies have tested HMD technology in relation to issues involving spatial navigation or visualization but studies involving the cognitive interpretation of real world objects (such as paintings) are very limited (Sharples et al, 2008). One hypothesis tested was whether participants become more immersed in the virtual gallery environment through the use of HMD technology. A number of researchers have noted that HMD technology has the potential create a different effect in relation to the emotional responses of the user (Kim et al, 2012). These effects are examined in this experiment which considers how the user interprets the virtual paintings from a visual standpoint, in addition to measuring how immersed they feel while interacting with the art gallery. The

Figure 3. The Experimental Set-Up Showing the SONY HMZ T1 HMD (www.sony.com).

ultimate goal of this experiment is to generate data that may assist in the development of guidelines to improve the display of artworks, such as paintings, in virtual galleries. The data collected provides a qualitative analysis which will be of use to those designing interactive three-dimensional environments. The results are quantified for an objective understanding of how the properties of three-dimensional environments and objects influence the user experience. It was predicted that fluctuations of the user's sense of immersion and presence would be present and influenced by the changes in the dimensionality of the display technology. These changes may in turn influence the user's behaviour in relation to their engagement with the virtual gallery.

The first section of the experiment used a group of participants split into two separate groups. The demographics of this sample of 12 participants were 8 males and 4 females, between the ages of 19-36. The participants each observed four visual art pieces; two paintings and two digital art creations, on a laptop screen. One group viewed them using a PowerPoint slide deck, controlling the slides at will. The other group viewed the artworks via an avatar in a virtual gallery in Second Life. After viewing the artwork each group of participants then viewed the artwork using the display mode from the other group.

The second section of the experiment again consisted of a large group of participants each observing the same four visual art pieces. This section of the experiment again split the group of participants into

two separate groups. The demographics of this sample of 21 participants were 14 males and 7 females, between the ages of 18-35. This time, all of the participants interacted in the art work via the SONY HMZ T1 Head Mounted Display (Figure 3). One group viewed them using a PowerPoint slide deck, controlling the slides at will. The other group viewed the artworks via an avatar in a virtual gallery in Second Life. After viewing the artwork each group of participants then viewed the artwork using the display mode from the other group.

Within each display modality, each participant viewed four pieces of artwork (Figure 4):

- Duke of Berry on a Journey by the Limbourg Brothers (1370-1416)
- Sunday Afternoon on the Island of Grand-Jatte by Georges Seurat (1884-1886)
- Digital Art rendition of Japanese game Okami (2006)
- Digital Art rendition of a Halo character from the Halo Wars game (2009).

The experiments were carried out in a human-computer interaction laboratory on the SUNY Oswego campus. Dell laptop computers based in the laboratory were used as the platform device which participants used to operate the PowerPoint slidedeck and control the Second Life avatar (on screen or using the HMD). Default settings were used in Second Life to prevent color and contrast biases. Low external lighting helped with immersion and to eliminate unnecessary visual distractions. During the second section of the experiment users had already been introduced to Second Life on the laptop screen, they just needed to be shown how to properly attach and wear the HMD to complete this portion of the experiment.

One of the principle data collection instruments used in this study was questionnaires. Two different types of questionnaire were used in this experiment: a pre-test questionnaire, and a post-test questionnaire. The pre-test questionnaire took the form of a survey given to each participant before they started the experiment and consisted of thirteen questions relating to demographic information. The pre-test questionnaire also gauges the user's level of experience of, and usage of, related technology, and their experience with computer gaming and also their inherent familiarity with, and appreciation of art. The post-test questionnaire is a survey given to the participant after they had viewed the virtual artwork. It consisted of twenty six questions arranged in a specific manner to allow the collection of information relating to the user's visual analysis of the artworks studied, their embodied cognitive experience, and the interaction they experienced.

Although each question on the questionnaire belonged to a specific category (relating to a specific attribute), the questions were not categorized and were randomly arranged. The participants were not made aware of the motives behind the questions being asked. These categories were used for an analysis

Figure 4. The Four Artworks Used in the Experiment (two paintings and two digital art creations).

to compute differences between color, brightness, immersion, presence, engagement, and interactivity with the interface. Each question used a Likert scale for the response, with numerical values from 1 to 10.

The experimental procedure involved each participant arriving at the laboratory individually. They were asked to have a seat and were briefly told about the nature of the study. The use of the three-dimensional environments and the visualization of paintings were explained. The users were then informed that they would be participating by either visualizing the paintings on a laptop screen and using a Head Mounted Display. Next, they were asked to sign an informed consent form. When the subject was ready and comfortable, the participants filled out the pre-test questionnaire to gather the general demographic information. After completing the pre-test questionnaire each participant was given control of the laptop and allowed to begin. For the group viewing PowerPoint, the paintings were already visible on the screen. For the group using a Second Life environment, the onscreen avatar was positioned near the paintings so the participant could use the avatar to walk around and view the paintings with ease. The participants started the task until they were deemed to have finished, at their own discretion. The post-test questionnaire was given to all participants after they had finished viewing the virtual artworks. Finally, a short debriefing of the experiment was given to all participants and information sheets were given to each participant to explain about the purpose of the study and the hypotheses being investigated.

RESULTS

Initially, a number of paired T-Tests were conducted to analyse the results of the first section of the experiment. This allowed the comparison of the view of the art in PowerPoint on the laptop display screen with the screen view of the virtual art in Second Life. The T-Tests were based on the categorization of the survey results into visual, immersive and interactive facets of the experience. The results from the second section of the experiment (using the HMD) were then introduced and a comparison of the differing modalities was made.

Attribute 1: Visual

Three of the questions on the post-test questionnaire asked participants how they perceived the color of the paintings on a scale from one to ten. Four questions asked the participants how they perceived the brightness of the paintings. A paired T-Test was conducted to compare the overall visual quality of the screen view of the virtual art in Second Life with view of the art in PowerPoint on the laptop display screen (Figure 5).

There was a significant difference (P=0.006) in the scores for the visual component of the survey for the virtual environment (M=7.143, SD=2.399) and the PowerPoint experience (M=8.286, SD=1.013). There is enough evidence to suggest that when viewing the virtual artworks, the visual components related to the color and brightness of the artworks are affected by the display technology being used; this includes the medium of presentation. The implication is that the virtual environment of Second Life is interpreted by the viewer as a significantly different mode of display to that used by a PowerPoint presentation.

The user's perception of the spectrum of colors and brightness is considrably altered with the change of medium. This can be explained, to some extent, using the theory of simultaneous contrast, which describes how the brain will perceive two identical colors differently when superimposed with a different

Figure 5. The Visual T-Test Results.

Paired T-Test and CI: Second Life Visual, PowerPoint Visual

Paired T for Second Life Visual - PowerPoint Visual

	N	Mean	St Dev	SE Mean
Second Life Visual	28	7.143	2.399	0.453
PowerPoint Visual	28	8.286	1.013	0.191
Difference	28	-1.143	2.031	0.384

95% CI for mean difference: (-1.931, -0.355)
T-Test of mean difference = 0 (vs not = 0): T-value = -2.98 P-Value = 0.006

contrasting background (Douma, 2006). This may explain why, for the viewer, the visual component in Second Life (which provides a juxtaposition of the artwork and virtual environment) differs so much from the full screen PowerPoint presentation of the artwork.

Attribute 2: Immersion

Eleven of the questions on the post-test questionnaire asked participants about their ability to predict actions in the environment and about their awareness of surrounding events. A paired T-Test was conducted to compare the overall immersive nature of the screen view of the virtual art in Second Life with view of the art in PowerPoint on the laptop display screen (Figure 6). There was no significant difference (P=0.972) in the scores for the immersive component of the survey for the virtual environment (M=6.727, SD=2.697) and the PowerPoint experience (M=6.75, SD=3.279). Hence, there was not enough evidence to suggest any difference in immersion due to the means of display. Hence, we can infer that the cognitive and immersive characteristics of viewing the paintings in a virtual art gallery remain similar to viewing the paintings full-screen on a laptop.

Figure 6. The Immersive T-Test Results.

Paired T-Test and CI: Second Life Cognitive, PowerPoint Cognitive

Paired T for Second Life Cognitive - PowerPoint Cognitive

	N	Mean	St Dev	SE Mean
Second Life Cognitive	44	6.727	2.679	0.404
PowerPoint Cognitive	44	6.750	3.279	0.494
Difference	44	-0.023	4.321	0.651

95% CI for mean difference: (-1.337, 1.291)
T-Test of mean difference = 0 (vs not = 0): T-value = -0.03 P-Value = 0.972

Attribute 3: Interaction

Seven of the questions asked participants how they felt about their engagement and interaction with virtual environment and the PowerPoint experience of viewing the paintings. A paired T-Test was conducted to compare the overall quality of the interaction experience of the screen view of the virtual art in Second Life with view of the art in PowerPoint on the laptop display screen (Figure 7).

There was a significant difference (P=0.045) in the scores for the interactive component of the survey for the virtual environment (M=6.313, SD=2.901) and the PowerPoint experience (M=7.688, SD=2.62). The way the questions were formulated, the more difficult the interaction was, the lower the participant would rate the score. If interaction interfered with the viewing of the art, then participants would give a low rating. There is enough evidence to suggest that there is a difference in the mean scores of the interaction, with the PowerPoint experience being rated as easier to use. The easier the experience of interaction is for the user, the more analogous that experience can be seen to correlate to real life, and thus perhaps seem more natural to the user.

This result may potentially have an effect on the user's perception of the painting in terms of immersion. Referring to Milgram and Kishino's taxonomy (1994), we may hypothesize that a painting would be perceived differently, and the user would experience varying degrees of immersion, if they were to experience the art at different points along the virtuality continuum. If the interaction with an interface becomes too complex, then the experience feels disjointed, breaking the feeling of immersion, and thus, any attempt to enjoy the artwork becomes difficult and counterproductive.

Comparing Attributes 1 and 2: Visual and Immersion

For this section of the analysis, the post-test questionnaire results for both the visual attribute and the immersive attribute were collected for the PowerPoint screen experience (PP), the Second Life screen experience (SL) and the Second Life HMD experience (VR). These attributes were plotted as a series of scatter plots demonstrating the relationship between the visual aspects that affected the user when viewing the artworks and the immersive nature of the viewer's experience while using each of these different display mechanisms (Figure 8).

Figure 7. The Interaction T-Test Results.

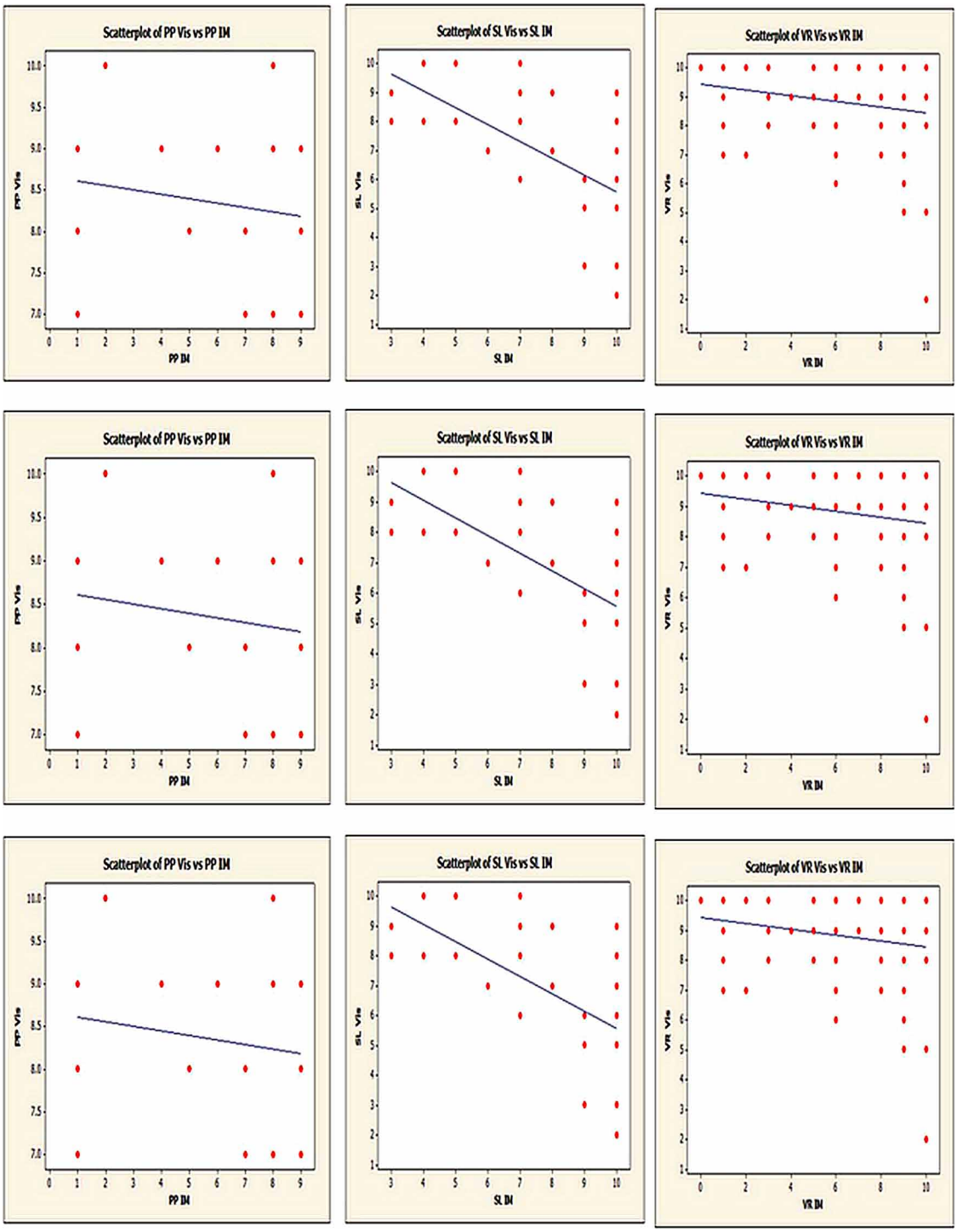
Paired T-Test and CI: Second Life Interactive, PowerPoint Interactive

Paired T for Second Life Interactive - PowerPoint Interactive

	N	Mean	St Dev	SE Mean
Second Life Interactive	32	6.313	2.901	0.513
PowerPoint Interactive	32	7.688	2.620	0.463
Difference	32	-1.375	3.731	0.660

95% CI for mean difference: (-2.720, -0.030)
T-Test of mean difference = 0 (vs not = 0): T-value = -2.08 P-Value = 0.045

Figure 8. A Comparison of the Visual and Immersive Aspects of a Range of Displays.



All three experiments revealed a negative slope when visual aspects were plotted against the immersive aspects of the experience. It would appear that as the levels of immersion increased, the perceived visual brightness and lightness decreased. The PowerPoint slope is less negative than the others, the visual rating never dropped below a rating of 7. The PowerPoint experience itself indicates a wide range of immersion ratings ranging from 1-9. The Second Life chart displays a more negative slope. The perceived quality of the visual experience decreases at a greater rate as the user perception of immersion increases. This implies that the increasing immersion experienced by the user in the virtual environment leads to a perception of decreased color and brightness quality, or acute visuals. This correlates with results from other research undertaken in this field (Vangorp, 2009).

It is possible that since the user understands that they are manipulating an avatar representation of themselves through a virtual environment their perception of the visual quality is being diminished (potentially linked to the discussion for the attributes in the previous section). Hence, the virtual environment artwork is perceived to not be as realistic as a digital representation of a painting on a PowerPoint slide, even though the actual digital artifacts are identical in both environments. It is also possibe that the user of a virtual environment becomes more distracted by the surrounding context of the 3D graphics. The 3D virtual world itself is perhaps more visually interesting or alluring than the mere reproduction of the artwork that is "re-represented" inside that world. The quality of visuals shows a significant drop when compared to the high ratings recorded for the PowerPoint experience. The Second Life chart clearly demonstrates an increased density of plot points on the scatterplot in the lower right region, where users recorded lower visual ratings in what was perceived to be a more immersive environment (based on responses to the relevant survey questions).

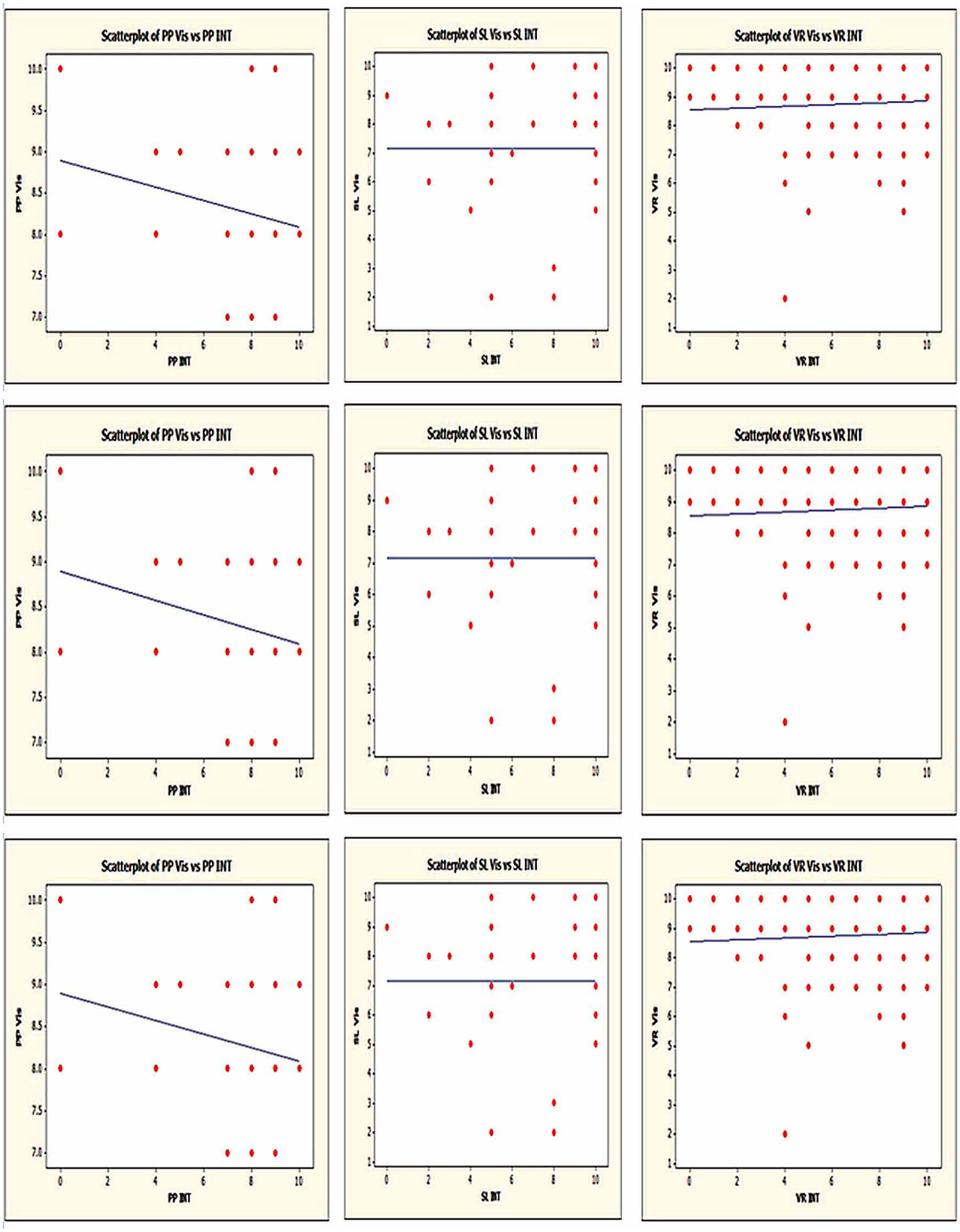
Overall, the HMD chart displays a dense, high scoring visual acuity data area indicating that the users perceived this as a high quality visual experience. This is similar to the data recorded for the PowerPoint mode. However, once again as perceived immersion increased, the perception of visual quality begins to decrease - a similar trend as was seen in the Second Life chart. The HMD displays the visuals at a greater perceived resolution than the Second Life screen display. As immersion increases within the HMD environment, the interpolated slope is again negative.

Hence, the visual quality (in terms of level of light and visual brightness) associated with the artwork as perceived by the user, appears to slightly reduce at higher levels of user immersion.

Comparing Attributes 1 and 3: Visual and Interaction

For this section of the analysis, the post-test questionnaire results for both the visual attribute and the interactive attribute were collected for the PowerPoint screen experience (PP), the Second Life screen experience (SL) and the Second Life HMD experience (VR). These attributes were plotted as a series of scatter plots demonstrating the relationship between the visual aspects of the experience and the interactive nature of the experience while viewing artworks on these different display mechanisms (Figure 9). The PowerPoint slide deck was the only experiment to display a slight negative slope when visual acuity was plotted against interaction. As ease of interaction and general feel of control increased, the user's perceived visual quality slightly decreased. Through analysis of the video from the experiments, it was noted that some users did not like the control mechanism to view the slides in PowerPoint, while others seemed to feel as if they were already accustomed to it and generally comfortable. The visual quality never drops below 7 during the PowerPoint experience. In the Second Life chart, the slope is almost flat,

Figure 9. A Comparison of the Visual and Interactive Aspects of a Range of Displays.



with a slight increase. As the interaction rating increased, the visual quality rating slightly increased. The highest clusters of interaction ratings were midrange, around 5. These clusters contributed to the balancing of the slope, to make it almost horizontal.

The HMD chart displays a slightly positive slope this time with the visual rating increasing as ease of interaction increases. Although the Second Life and HMD experiments utilize the same virtual interface in Second Life, the higher clusters in the 6-10 range of interaction on the HMD chart are not present on the Second Life screen chart. This analysis suggests that visual acuity is not significantly affected by changes in the interaction metaphor.

Comparing Attributes 2 and 3: Immersion and Interaction

For this section of the analysis, the post-test questionnaire results for both the immersion attribute and the interactive attribute were collected for the PowerPoint screen experience (PP), the Second Life screen experience (SL) and the Second Life HMD experience (VR). These attributes were plotted as a series of scatter plots demonstrating the relationship between the immersive aspects of the experience and the interactive nature of the experience while using these different display mechanisms (Figure 10).

The PowerPoint chart displays a relatively flat slope when interaction rating is plotted against user perceived immersion. This interpolated trend indicates that there isn't a substantial positive or negative correlation between these two components. This implies that users did not experience a change in how easy they felt the system was to use, as their perceived level of immersion varied. The Second Life chart displays a slight positive slope between interaction rating and user immersion. As immersion increases, the ease of interaction appears to slightly increase.

The HMD chart displays the most positive slope of the set when plotting interaction rating against user immersion. This seems to suggest that the more immersive the experience, the easier the interaction and the easier the interaction, the more immersive the experience.

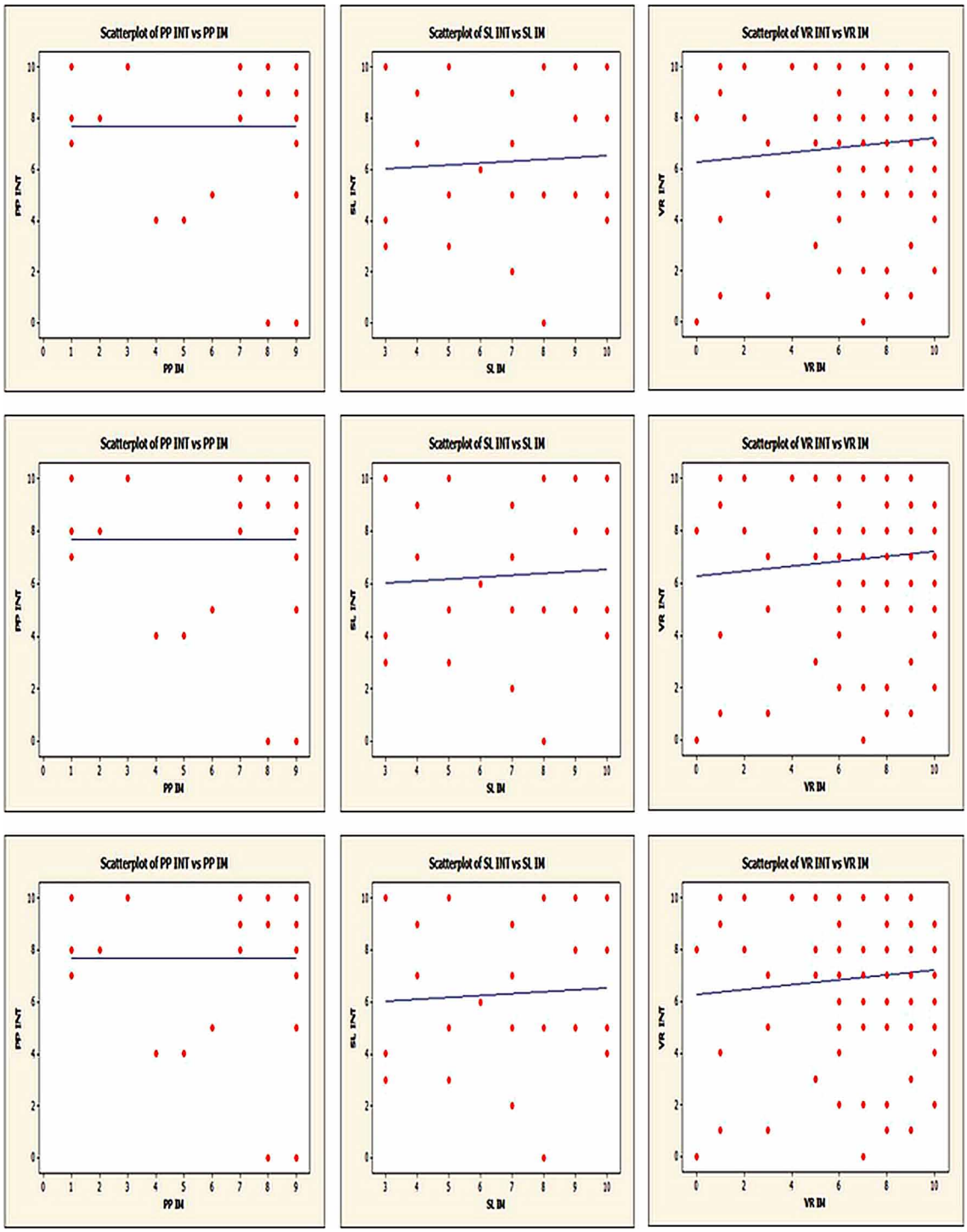
The clusters are most dense in the ranges of 6-10, showing an overall ease of use with a high level of immersion when a HMD is used. This result agrees with much of the previous research in the use of HMDs in similar fields (Grau, 2004; Mäyrä & Ermi, 2005; Shaples et al, 2008; Kim et al, 2012).

Additional Results Summary

In summary these results also show that in this comparison:

- The PowerPoint slidedeck shown on a screen and the HMD mode of display both generally register higher visual acuity with the participants than the viewing art in a Second Life Virtual gallery using a screen display.
- There is no significant difference distinction regarding the perceived interaction quality between the various display modes used.
- As expected the HMD display was perceived to be the most immersive of the display technologies. The three-dimensional virtual art gallery environments were also reported as more immersive than the two-dimensional views of artworks shown on screens.

Figure 10. A Comparison of the Immersive and Interactive Aspects of a Range of Displays.



DISCUSSION

The experiments described in this paper collected a range of data comparing the screen view of the virtual art in Second Life with views of the art in PowerPoint on a laptop display screen. These results were then compared with users who viewed the same worls of art using a HMD as the mode of display. The survey results were categorized based on the visual quality of the experience as rated by the user, the immersive (cognitive) nature of the experience and the ease of interaction (Figure 11).

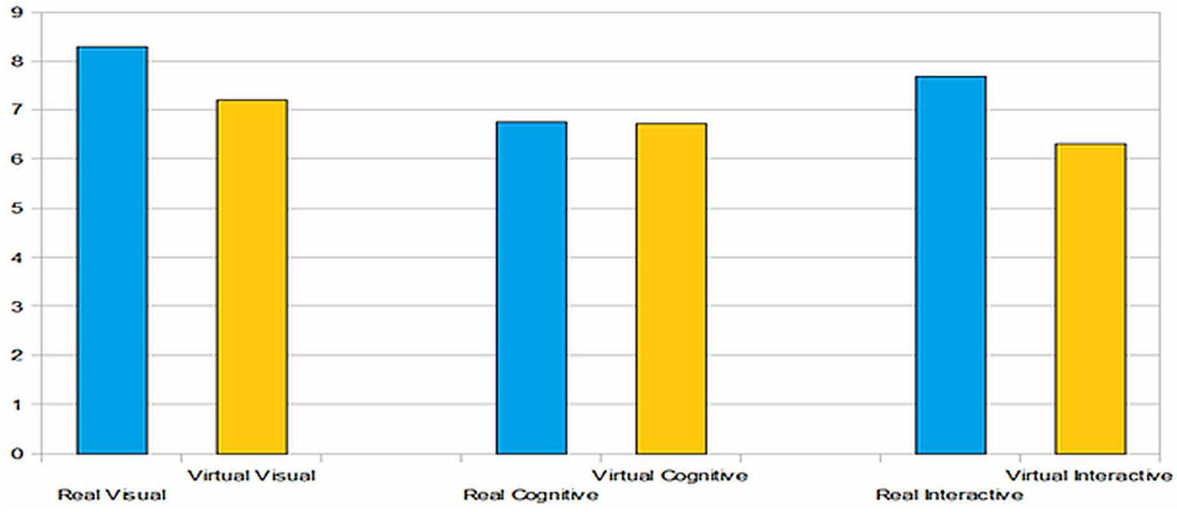
Attribute 1: Visual

The first attribute to be considered was the optical quality, or visual acuity. The initial experimental session compared art displayed within a virtual gallery environment to art viewed directly on a computer screen (using PowerPoint). The results showed that the human eye will potentially perceive color and brightness differently when viewing art in each of these cases. The lower visual acuity score for the participant's viewing of the artworks in the virtual environment could suggest two possible hypotheses;

1. The Size of the Screen Affected the Viewer's Perception.

Although the size of the screen could be adjusted, the size of the typical computer monitor screen is typically between 13 and 20 inches. The images displayed using PowerPoint utilized all of the screen real estate whereas the Second Life art gallery environment itself utilized the entire screen real estate, with the painting displayed as an object within the environment being viewed on screen. Essentially, visiting the Second Life virtual gallery meant that the user was always viewing a smaller version of the artwork on the screen (Grau, 2004; Douma, 2006; Popper, 2007; Dethridge, 2011). The user does however have the ability, within the Second Life environment, to walk their avatar to an ideal position right in front

Figure 11. A Comparison of Mean Ratings for the Attributes Examined (Direct View vs Virtual Environment).



of the painting and switch from a 3rd person (exocentric) to a 1st person (egocentric) view and achieve a similar full screen view of the painting – but, even so, this requires a command of the navigation controls. Often the user's view in the virtual world may still be slightly angled or bordered when compared to the full screen PowerPoint images. The HMD interface allows the user to view the interface on a perceived display that is equivalent to a 70 inch screen, this potentially alleviates the reduction in artwork size experienced by users when viewing the virtual environment on a screen.

2. The Virtual Environment Created a Poor Color Contrast.

Poor color contrast could be a result of a simultaneous contrast of colors in the artwork interacting with adjacent colors when viewing art on the walls of the Second Life virtual art gallery. When using the PowerPoint screen to view artwork, there are no other interactions of color or brightness other than those within the frame of the laptop screen itself. One could see this simultaneous color contrast as unavoidable in virtual environments used for this purpose. The effect could potentially be avoided within a Second Life virtual art gallery if there was an option to select a painting and have it appear on screen in full, but then then the user would potentially lose some of the immersive aspects that are enhanced by the sense of presence the user feels within the virtual environment.

Attribute 2: Immersion

The second attribute to be considered was the immersive nature of the experience for the user. There appears to be no difference in the user's measured cognitive/immersive engagement between viewing the works of art from a virtual screen in Second Life or via PowerPoint on the laptop screen. Since presence and immersion did not appear to be affected by either display type, the only significant variable worth noting in this regard came from the analysis of the experimental videos. It was noted that participants spent significantly longer time in the virtual environment viewing the works of art than they did looking at the digital images directly on screen. Although, time spent is often considered as a variable of engagement, this discrepancy could also be a factor of the difficulty experienced by users when navigating around the virtual environment compared to viewing the paintings directly on the screen.

This lack of difference recorded during this experiment between these measures could also perhaps be interpreted as illustrating how the virtual art gallery environment may provide a realistic environment for the user to view the paintings. The similar perceived levels of engagement between the various display modes may also suggest that there was no significant metaphor used by the viewers for visual augmentation and that natural mappings were used by the users (Grau, 2004; Kuspit, 2005; Popper, 2007; Schubert et al, 2008). This result suggests that perhaps these mappings were similar when using either of the display mechanisms. Experimental results from human factors, perceptual studies, and cognitive science can help explain this effect. Often, as the fidelity of digital images improves, enabled by technology, research has shown the user's ability to interpret and comprehend visual rhetoric increases. Users become able to see 'through' the interface, and their interactions become natural and more accurate as restrictions (due to previous technological limitations) are removed (Azuma et al, 2001; Davidson et al, 2003).

Perhaps the Second Life virtual art gallery was seen by the participants as a lower resolution environment when compared to other, more familiar, virtual worlds such as computer games. Or perhaps the Second Life user is distracted by the surrounding 3D graphics which may diminish the "re-representation" of the

artwork displayed on a screen inside that world. A larger study involving more participants, examining the individual components that make up the immersion rating may allow a better understanding of this attribute and its effect (if any) on the user experience.

Attribute 3: Human-Computer Interaction

The third attribute to be considered was the ease of interaction experienced by the users. As was to be expected, controlling and navigating an avatar around in a virtual environment with a mouse and keyboard appeared to have more functionality issues than viewing consecutive slides on PowerPoint. Some of the participants in the study who used Second Life to view the art work were able to easily move around the environment. However, some users of Second Life seemedto encounter difficulties and were less able to manipulate the view into a position they wanted in order to enjoy the art work.

The lower scores recorded for the Second Life environment could indicate that users were not as comfortable in the virtual art gallery or perhaps had difficulty controlling the movements and interactions. The pre-test questionnaire indicated that many of them were already familiar with computer software and virtual environments, and knew how to use both Second Life and PowerPoint. Hence, one would not have expected to encounter significant issues with the user's ability to control and navigate their avatar in the virtual art gallery.

The rating for interactivity could possibly be correlated with the ratings for attribute 1 (visual acuity). The user's view of the paintings in the virtual art gallery (specifically the angles and sizes) is where the difference in the mean reponses may be significant. When analyzing the video of the experiment participants interacting with the virtual gallery, it can be seen that some participants had difficulty viewing the paintings the way they wanted to, in contrast to the fixed position of the PowerPoint experience.

The results of the experiments comparing Second Life to PowerPoint indicate several key correlations. Generally, as perceived visual quality increases, immersion decreases. The more immersed a user is in the virtual environment, the less visually acute the paintings were perceived to be. Previous research has reported similar findings (Robinett, 1992; Brysnon, 1994; Grau, 2004; Malby, 2009; Calleja, 2011) and Milgrim and Kishino (1994) discuss this idea when they state that: *"A person who is using a virtual environment knows they are in a virtual environment."* This concept may explain the difference with the participant's perception of the visuals in the virtual environment compared to those viewed directly on screen. The paintings viewed directly on the PowerPoint screen had a less negatively correlated slope than the paintings viewed in Second Life. Perhaps, since PowerPoint is perceived to be less immersive, the visuals were perceived to be of higher quality. As the users interacted with Second Life, they felt less immersed in the gallery environment when interacting with the paintings that were perceived to be of lower quality.

The data also showed that the participant's perceived ease of interaction increased with increased visual quality. With the PowerPoint experience on a laptop screen, the interaction mechanism was simple and a visual quality increase was noticed, while simultaneously, the user's feeling of immersion decreased. In the Second Life virtual environment, the interaction appeared to be more engaging. In this case, as visual quality increased, the ease of interaction also increased. Finally as the perceived ease of interaction increased, the user's sense of immersion also increased. Increased visual quality only had a positive effect on immersion when ease of interaction was considered.

Discussion Summary

The trends discussed above become particularly evident when comparing the Second Life user experience via the laptop screen to the Second Life user experience using a HMD. The virtual interface and the artworks being viewed are exactly the same. However, users viewing the artowrks with the HMD reported significantly increased visual quality. There was also an increased slope on the data charts that indicated an increased ease of interaction. A more positive slope was noted regarding ease of interaction against level of immersion and a less negative slope for visual quality against level of immersion. Hence, it can be seen that these perceived increases in visual quality (attributed to the HMD display) lead to a greater ease of interaction, which in turn increases the level of immersion for the participant.

CONCLUSION

This study has shown that different modes of display of virtual artwork can offer very different user experiences. A user viewing artwork in a virtual environment such as Second Life must navigate around the virtual gallery using a more complex interface (usually a keyboard and mouse) to interact with the objects in the environment. This additional layer of interaction creates a new layer of experience. Thus, a user wishing to view art in a virtual environment may potentially have a more complex and richer experience than a user who browses online images in an art catalog. This study also showed that the cognitive elements of presence and immersion remain approximately the same for both experiences. This paper gives new insights into the viewing of art in virtual environments. We compare three attributes of human behavior ; human vision, embodied cognition and the human ability to interact with computers. Generally, as perceived visual quality increases, feelings of immersion decrease. The more immersed a user is in the virtual environment, the less visually acute the paintings were perceived to be. It is also possibe that the user of a virtual environment becomes less focused on the "art" as a discrete or bounded object and more distracted by the surrounding context or environment of the 3D graphics. The 3D virtual world itself is perhaps more visually interesting or alluring than the mere reproduction of the artwork that is re-represented inside that world. The study also suggests that the easier the experience of interaction is for the user, the more analogous that experience can be seen to correlate to real life, and thus perhaps seem more natural to the user.

When humans are "immersed" in virtual spaee, their navigation and perception of that space may simply overtake their interest in observing or scrutinizing a single aspect or instance (artwork) within the larger field of vision. As Manovich points out, the condition of "immersion" depends on the user being able to somehow forget the existence or appearances of "the real world." (Manovich, 2002) The results of this suggest that the more immersive the experience, the easier the interaction and the easier the interaction, the more immersive the experience. In virtual environments, the user's ability to distinguish the qualities of one particular artwork may diminish in relation to their immersion in an entirely artfully constructed graphic environment. While there are many ways to increase immersion and presence felt by a user within a virtual environment, it should be remembered that for the user (Dethridge, 2011): *"Virtual experience is the sum of their experience and is not enhanced or augmented by an ability to compare the virtual with the real"*.

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