A virtual perspective: measuring engagement and perspective in virtual art galleries

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Abstract: This paper describes a research project which attempts to analyse human perception of and interaction with virtual art representations in an online, three-dimensional graphic environment. Specifically, discerning how user experience may relate to engagement, immersion and interaction. A series of experiments are described, involving participants who experienced virtual artworks in multiple gallery environments and utilise different viewing perspectives. The paper then provides an analysis of the data recorded and gathered during user-testing. The experiments are undertaken within a specific virtual art gallery in the online virtual world *Second Life*. Demographic data is linked to the user experience focusing on the use of first person (egocentric) and third person (exocentric) screen perspectives. An examination of the user's perception of both two-dimensional and three-dimensional virtual artefacts is also provided. This paper concludes with an insight into the usability and effectiveness of designing, presenting and experiencing art in a three-dimensional virtual environment.

Keywords: virtual reality; art gallery; immersion; engagement; presence; perspective.

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1 Introduction

Virtual reality (VR) systems have been in existence for many years with their technical advances following the developmental curve of computing technology. Increasingly, within the last decade, realistic looking environments and images have begun to appear in the displays of many mainstream applications. Various conceptions of VR involve specialised immersive setups such as head-mounted displays (HMDs), stereoscopic three-dimensional displays, movement capture and haptic feedback. Accepted definitions of VR often refer to a broad spectrum of implementations including everything from text-based adventure games to the simulated, immersive world of *The Matrix* (Silver et al., 1999). The image on the screen represents the user's view of the world and may be presented in various ways. We examine the user perspective as related to the avatar, a graphical representation of the user's viewpoint within the virtual world. One such onscreen viewpoint is known as first person or egocentric. Another viewpoint may position the user's perspective somewhere outside the avatar's position in the action (third person or exocentric) view. From a design standpoint, there is a need to understand the user's perception of self when immersed in such worlds.

One of the many possible applications for such interactive, real-time technology is in the development of virtual art galleries which allow artists and enthusiasts to showcase art works in an accessible online environment. Virtual exhibitions can provide an affordable way for artists to showcase their work online to a larger audience. The nature of virtual environments allows for many possibilities that could not be achieved in the real world – such as gravity-defying sculptures, living paintings and the use of intriguing scale and graphic illusion. Such techniques allow online visitors to view and interact with the artwork. As general examples, both the official site for the Louvre (http://www.louvre.fr/en) and Washington's National Gallery of Art (http://www.nga.gov) have virtual tours for some sections of their collections. Virtual galleries could theoretically be built inside any existing virtual environment and can either recreates a real museum or gallery location (such as the Louvre's 'Explore in 3D' section of their online gallery) or the art works can stand alone, abstracted, with no real-world counterpart.

This study examines human interaction with real and virtual artworks within the virtual environment of *Second Life*. Users of this shared online space may interact with each other and with software to construct virtual characters, landscapes, objects and scenarios using graphic modelling tools (http://www.secondlife.com). Launched in 2003 *Second Life* is a shared, multiplayer online virtual world which allows users to interact with each other and with the environment. Multimedia (images, audio, movies and photographic images) can also be attached to virtual objects and viewed by those exploring the virtual space. Users may visit many virtual counterparts to real life locations including corporations, universities and other types of organisations.

Such shared online spaces are known as 'persistent' as they are designed to exist online 24 hours a day and be accessible by users at any time. *Second Life* has many communication functions and users can communicate with others in their avatar form using messaging, chat and real-time spoken audio functions. This makes *Second Life* a versatile social networking environment as users can form groups and exchange files.

This paper will introduce and define concepts along the 'real-virtual' continuum including augmented reality (AR), augmented virtuality (AV) and mixed reality. A description of how we can use and apply these concepts in the context of virtual art galleries will be given. The main body of this paper is concerned with an experiment undertaken to determine how immersion with a virtual art experience is related to user interest in the subject matter, to levels of engagement, to levels of interactivity and to user familiarity with the tools. The concluding section of this paper identifies key factors that are useful to consider when developing online displays of virtual art.

2 Reality, mixed reality and VR

The idea of a formal definition for the spectrum of real and virtual was first developed in the seminal paper 'A taxonomy of mixed reality visual displays' by Milgram and Kishino (1994). According to Milgram and Kishino, we may understand VR by observing a 'virtuality continuum' which encompasses both 'real' and technologically augmented forms of visual representation. This scheme is simply laid out as a linear path between the quintessential 'real' and the quintessential 'virtual'. At one end is the real world of physical objects and at the other is a purely virtual computer generated world (Figure 1).

The taxonomy of Milgram and Kishino (1994) classifies objects as either real or virtual depending upon two factors. On one hand, *reality* is defined by objects which have an actual physical existence; on the other hand, *reality* is also defined by the authors according to the means by which an object is displayed in a media context. In this context, direct viewing is defined as seeing the actual object itself while non-direct viewing is seeing it recreated by some type of display or medium. Direct viewing of real objects can be considered to be technically at the maximum possible resolution, as real objects may be observed down to the level of atomic particles and beyond. Therefore, theoretically, resynthesising these objects loses content no matter what digital resolution is used.

Figure 1 The reality-virtuality continuum (see online version for colours)

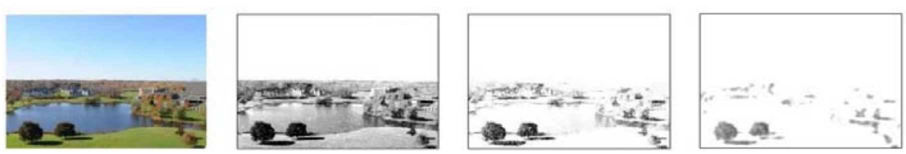
However, this does not necessarily affect the perceived quality of the experience, as the viewer's sensory faculties only permit a certain level of detail. Using currently available technologies, it is possible for purely virtual objects to be presented at qualities (or resolutions) which match our human perception of directly viewed real objects.

Any attempt to define a synthesised object as being either real or virtual is difficult because the classification is absolute while the qualities and characteristics of the representation are not. There will even be a point at which the synthesised object will completely disconnect perceptually from what it is intended to represent.

According to Milgram and Kishino (1994), the quality of an image may broadly impact the viewer's perception of an object and directly relate to its quality. This term 'realness' can be used to describe a quality of perception as well as the accuracy of reproduction. The synthesised object may no longer accurately represent the real object although it may be perceived as real. Virtual objects may not exist in the real world as real objects but they may appear to the user as real.

In Figure 2, is it practical to consider the representation of the landscape in the fourth frame as a real object? If we keep lowering the quality of the image, the environment will eventually cease to be recognisable as anything at all. Hence, any proposed virtual taxonomy perhaps needs a gradating classification in order to describe the resolution of synthesised objects.

Figure 2 Demonstrating the progressive degradation of an image (see online version for colours)



2.1 Augmented and mixed reality

Towards the 'real' end of the Milgram/Kishino spectrum is the realm of AR which describes the use of virtual information which is projected by computer or photographic media into a primarily real experience. AR displays may include heads up displays (HUDs) which provide the user with a transparent screen that enhances augments their view of the world with additional digital information. Specific examples include computer software devices like global positioning systems (GPS), Google Maps which superimpose road lines and labels onto real world satellite images and Google Glass which superimposes graphical data and images over the real world. Other examples include AR navigation systems on mobile phones where the user can see the location of nearby areas of interest, such as the tube/subway stations shown in the application in Figure 3.

These systems use a mix of photographic and abstract symbols to convey information to the user and may be seen in Milgram and Kishino's terms as 'mixed reality systems'. Alongside AR sits the less mainstream AV which describes a synthetic or virtual world mediated or shared by real objects or elements. These include tangible game controllers such as a guitar, sword or gun. The tangible interface allows a user to control a similar virtual object (guitar, sword or gun) as part of the action on-screen. In this way, virtual objects can imitate 'real' objects to increase the immersion felt by the game players.

Figure 3 AR mobile phone application to locate tube stations in London (Acrossair©) (see online version for colours)

Milgram and Kishino (1994) discuss the dimensions applicable to ‘merging real and virtual worlds’. These three dimensions can be used to create a map that describes for the user an experience of how realistic or immersive an environment is. They take into account three key metaphors which express how realistic or immersive an environment may appear:

- *Extent of world knowledge* (*EWK*) describes ‘how much information exists in the world’. This is often useful when assessing whether a design is logical and structured. It refers to the number and breadth of objects and information which exist in the world. For example, this metaphor allows us to compare a gameworld in which there is a maze of identical hallways with one that has a richer environment with a greater variation of interiors and landscapes.
- *Reproduction fidelity* (*RF*) refers to the level of detail that is displayed onscreen. This takes into account resolution and the graphical detail of the world. It also deals with dimensions of display such as two-dimensional sprites, three-dimensional models rendered for a two-dimensional display or three-dimensional models displayed in three-dimensions. RF relates to the whole quality of the visual presentation and would logically extend to include all the sensory information provided for the user in the virtual world.
- *Extent of presence metaphor* (*EPM*) also refers to how the world is visually presented. It accounts for viewing modes such as in a panoramic display or a HMD unit. It also considers interactive features such as head-tracking and feedback. This metaphor accounts for interactivity features which allow the user to control their impact on the virtual world, from buttons and text input to full body suits and head-tracking.

Described in more simple terms, these three attributes look at the content of the world (EWK), the presentation quality of the world (RF), and the quality of interaction (EPM).

Another early taxonomy used to describe ‘all varieties of technologically-mediated experience ‘or ‘synthetic experience’ was created by Robinett (1992). Rather than focus directly on distinctions between real and virtual, Robinett uses categories which define how the human user’s interactions with the world are enabled by categories of ‘mediating’ technology (Robinett, 1992).

These categories allow designers to consider the perspective, the dimensions, feelings and tools that the user experiences within the virtual world. They also focus on the sensory feedback a user may receive from a virtual environment. The first person (egocentric) perspective does not include an onscreen image of the user’s avatar. Hence, the expectations for realistic sensation may diverge from what is expected in a third person user perspective (exocentric.)

For example, a viewer controlling a virtual avatar with a first person viewpoint may receive haptic, feeling or sensory feedback as if the events in the world are happening to them. This extra feedback may enhance their field of perception by providing information about off-screen events. Such techniques suggest another way of classifying the user’s virtual experience which considers the level of sensory stimulation and reproduction. We may classify VR systems according to which systems of human perception they stimulate and to what effect.

Table 1 A classification system for types of synthetic experience

Dimension	*Possibilities*	*Contrasting examples*
Causality	Simulated	Flight simulator
	Recorded	Film
	Transmitted	Teleoperation
Model source	Scanned	Night vision goggles
	Constructed	Video game
	Computed	Computational fluid dynamics
	Edited	Film
Time	1-to-1	Film
	Accelerated (or retarded)	Time-lapse photography
	Frozen	Photograph
	Distorted	Edited video recording of event
Space	Registered	Night vision goggles
	Remote	Teleoperation
	Miniaturized (or enlarged)	Micro-teleoperation (STM)
	Distorted	STM with heights exaggerated
Superposition	Merged	Augmented reality
	Isolated	Virtual reality
Display type	HMD	Virtual reality
	Screen	Video game
	Speaker	Recorded music
	(*Many more*)	
Sensor type	Photomultiplier	Night vision goggles
	STM	Micro-Teleoperation
	Ultrasound scanner	Medical ‘X-rays’
	(*Many more*)	
Action measurement type	Tracker and glove	Virtual reality
	Joystick	Video game
	Force feedback arm	Teleoperation
	(*Many more*)	
Actuator type	Robot arm	Teleoperation
	STM tip	Micro-teleoperation
	Aircraft flaps	Remote piloted aircraft
	(*Many more*)	

Source: Robinett (1992)

2.2 Stepping into three dimensions

Virtual worlds embody realities created by the mind allowing them realisation as palpable entities. By entering a virtual world we allow its creators greater freedom to influence us, as at best they are controlling not just an object of our attention but the entirety of the world we are inhabiting (Ryan, 1999). These virtual environments can incorporate complex methods of control. The controls of simulation and training programmes may carefully mimic their real-world equivalents or even use identical hardware with haptic feedback (physical pressure, resistance, jostling or tilting). Complex simulators are used by the Air Force, Army, Navy and NASA as well as many business and industrial applications (Strickland, 2007; Schofield, 2011a; Wheelan, 2008).

The use of networked simulated three-dimensional worlds are a fast-growing area of application, as is evidenced by the popularity of massively multiplayer online role-playing games (MMORPGs) such as World of Warcraft (2004). Online, multi-person simulated environments, such as *Second Life*, are potentially more useful to users because their content includes real-world information about individuals, businesses, products and locations (Dethridge, 2009).

Using a virtual three-dimensional environment to display art may not only help recreate the experience of seeing it in person but also give willing artists greater freedom and dimension within to work in addition to being more accessible and far less expensive to operate than a physical location. One such world that is well-suited for displaying art is *Second Life* which is a 'social' three-dimensional environment. Other multi-user, interactive environments include Sony's PlayStation Home environment (http://us.playstation.com/psn/playstation-home/) and Habbo Hotel (http://www.habbo.com).

Although *Second Life* can be less compelling than an analogous real-world experience, it offers the ability to access content with no physical travel, drastically reduced expenses and reduces some restrictions of geographical and physical space/time reality. Transitions to digital content are also made simple as links and files can be placed appropriately in the environment and accessed instantly (Dethridge, 2009; Boulos et al., 2007; Berge, 2008; Warburton, 2009).

One important principle is that of 'immersion' which is used to describe how a user behaves in a virtual world. This quality helps us describe the value and quality of the user's virtual experience. The more immersed they are in the virtual world, the more the actual world recedes into the background. (Dethridge, 2009)

The attributes of presence and immersion may work well when used in systems with high levels of realism (Montoya et al., 2001; Wheelan, 2008). One study analysed group behaviour both inside and outside of virtual worlds and found strong correlations between immersion and behaviour. The experiment also showed that users can experience social factors such as embarrassment and co-presence in the virtual world and that these increase with immersion, or presence (Slater et al., 2006). In another study, a comparison between two-dimensional and three-dimensional videoconferencing showed that three-dimensional environments foster much higher levels of social presence (Hauber et al., 2005). A further study suggests that information observing and 'lurking' is likely to foster future active participation in virtual environments. Creating an open atmosphere and availability of information should be expected to encourage a willingness to engage and participate (Li and Lee, 2010). Increasing the realism of an avatar tends to increase feelings of presence with the exception of cases in which the gap between appearance and behaviour is large, with allowances for the effects of the 'uncanny valley' phenomenon (Bailenson et al., 2005; MacDorman, 2006). Another study revealed that gender effects seen in the real world can be seen reflected in gendered avatars used in virtual worlds. This all reflects trends in the real world and suggests that feelings of identity in avatars are crucial (Yee et al., 2007; Eastwick and Gardner, 2008). One constant theme that can be drawn from these experiments is that the salience and meaningfulness of virtual experiences increases with immersion.

Immersion is created by several factors that have been outlined by Milgram and Kishino's (1994) taxonomy including world content (EWK); production quality (RF) and interactivity (EPM). These dimensions are high-level and in order to fully specify all contingencies of virtual environments we must examine each one in greater depth. Of primary concern in this project is identifying the aspects of virtual art galleries that connect the users to reality and how they may influence the user's behaviour, experience and utility within the environments.

Three-dimensional environments provide large amounts of virtual visual content as well as the ability for the user to create or to link to story or narrative elements. In this way, virtual experiences add new dimensions to the online interactions. In analysing the behaviour of users, it is important to consider the information that exists in the EWK dimension and to compare this to the complexity of the EMP dimension.

3 The digitisation of art

Before high-quality images and photographs were available, museums and art galleries were the best option for observing many culturally important objects in significant detail. Even in today's age of high-quality reproductions and prints, the general public still visits art galleries. This social activity reinforces the desirability of seeing original art objects in a real context as opposed to looking at reproductions in a book or onscreen. People enjoy the experience of physically visiting a location which is demonstrated by the attendance spikes which occur during periods of economic downturn suggesting that people visit these locations in lieu of more expensive activities, such as vacations. It is likely that people value the educational, social and active components of visiting the museums or gallery as much as they like to observe the art works and learn about the exhibits (Goldstein, 2009).

Of particular note is the fact that painting and photo exhibits continue to attract attendance despite the prevalence of high-quality physical and digital reproduction. Some of this may be due to attendance factors including sociability, scale, professional arrangement and organisation. The viewer may perceive a sense of authenticity while viewing real artworks. Three-dimensional or sculptural artworks and artefacts are more expensive to reproduce and generally not easily available for viewing in a representative three-dimensional digital form. While it is not hard to find online images of sculpture, these are often reported to be less gratifying to the viewer when compared to seeing the objects firsthand (Miller et al., 2006).

While the virtual view does not encompass the scale and multidimensional detail of a real gallery, the online viewer has the advantage of accessing the work at all hours and is able to spend as much time with the object as they wish. In some cases, users may even download and save their favourite images. Stallabrass (2010) observes that the status of owning or viewing an ‘original’ digital artwork may be lost in the digitising process:

> “There are some examples of artists selling versions of online work in limited editions with certificates of authenticity (along the lines of video art), but the gesture appears even more absurd than with video, since the work also appears in its original form for access by anyone with an Internet connection.”

Artists are perhaps able to protect their intellectual property by display in glow-resolution images online and/or adding watermarks to their work until payment is received. In the contemporary online environment perhaps artists may embrace methods such as product merchandising, mail order or retail sale of physical reproductions in order to make a profit from their online art.

Digital image reproduction has not only opened artwork and proprietary content to reinterpretation, cultural hacking and subversion but has also allowed novel forms of art to develop (Stallabrass, 2010). Reworking and ‘mash-ups’ of logos, images, movie trailers and popular songs are commonplace online and can arguably be considered as a new art form (Outlaw, 2011).

The most common scenario for experiencing digital content is of ‘unmediated presence’ where the user can view objects and images directly onscreen, usually through a web-browser. As three-dimensional virtual worlds become more engaging, we may expect broader content and a wider variety of purposing, as the technologies used for the experience mature. The virtual environments of today were unthinkable just one or two decades ago. The results of technological evolution permeate many aspects of contemporary life (Schofield, 2012). There is no doubt that virtual worlds will continue to grow ever more immersive and to become capable of producing the types and qualities of artistic experience similar to those the viewer enjoys in the real world.

4 Testing the user experience of virtual art

The aim of this research is to examine the way virtual art is represented and viewed in a three-dimensional environment. This project asks how may an examination of the user experience help us understand the spectrum of reality and virtuality as it relates to media representations in a virtual gallery context? To answer this, the researchers identified and accounted for a number of possible factors which may influence the quality of the user experience. This project examined user behaviour and levels of immersion in virtual scenarios. In this research project, we endeavoured to determine how immersion is related to user interest in the subject matter, to levels of engagement, to levels of interactivity and to user familiarity with the tools. The experiments were built around an existing virtual art installation entitled Dark Luminance (Figure 4) co-designed by one of this paper’s authors (Dethridge, 2011).

A series of experiments was undertaken to examine multiple aspects of the user experience relating to environment usability. Users were surveyed and data was collected regarding the factors that contributed to a successful user experience. A number of demographic factors pertinent to each participant were collected, these included gender, age, assertiveness, computer use, and their interest level in art. These factors were then correlated with variables measured in the virtual environment, where the perspective of the user and the mode of presentation of the artworks were assessed. During the experimental sessions, the user experiences were recorded and the users were surveyed. This allowed for the acquisition of quantitative data. Affective data was also collected from the users after each trial. Video recordings of the user's behaviour were used to discern time spent viewing specific works and the actual behaviour of the user within the virtual world. This paper reports on the results of this experimental work and discusses the correlations linking demographic data to user experience gathered from the multiple methods of data acquisition that were applied.

Figure 4 Interacting with the Dark Luminance virtual art gallery (see online version for colours)

Source: Dethridge (2011)

4.1 *Experimental methodology*

This study utilised 24 participants who were recruited around the State University of New York, Oswego campus through social networks, bulletin board postings, and academic incentives for select courses. The participant group was composed of a range of demographics, although heavily weighted towards 20–25 year olds. A human-computer interaction (HCI) laboratory on the SUNY Oswego campus was used for this experiment. Laptops running the Windows 7 operating system were used as the platform on which *Second Life* and *Affect Map* software (to assess the emotional state of participants) was used for the trials. Graphic settings were balanced to achieve the highest level of visual quality while retaining consistently responsive interaction, this equated to a 'mid' quality setting in the *Second Life* preferences.

A number of questionnaires were used to collect data from the participants:

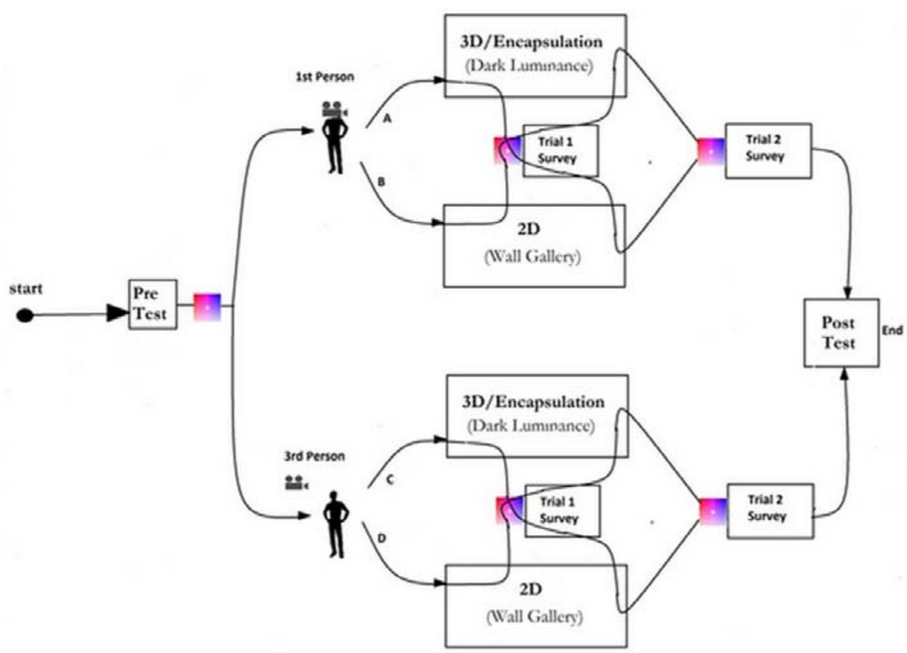
- A *pre-experimental* questionnaire was used to collect information regarding basic demographics, computer usage, virtual world experience/video game usage, assertiveness, interest in visual art and prior *Second Life* experience.

- After each trial (a visit to one of the two virtual art gallery locations) the participant was given a *post-trial questionnaire*. This collected data on their engagement, recollection of the art work, experience of the work, interest in the work and opinion of the control scheme.
- After both virtual environment sessions were completed a final *post-experimental questionnaire* was used to gather information about the overall engagement and enjoyment of the virtual experience, opinion of virtual worlds and enjoyment of the experienced art.

Before beginning their virtual art gallery experience and after each trial participants were instructed to select a value from the *Affect Map* software, a Java-based programme developed by one of the authors of this paper and designed to measure affect and activation (Ivancic and Taylor, 2010). This was used to provide information about whether the user's affective state had changed after each trial. Video recordings of the onscreen-events occurring during each of the trials were also recorded by a high-definition video camera. This was analysed to determine the time spent in each area and specific behaviours such as types of interactions, time, and control efficiency.

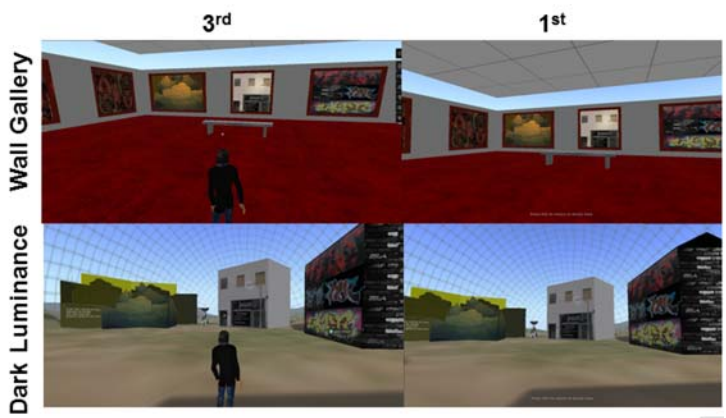
The design was a 2 × 2 mixed groups design, 50% of the participants used a 1st person perspective and the remaining 50% used a 3rd person perspective throughout the entire duration of their participation (Figure 5). These groups viewed two areas of the virtual art gallery in which identical works were displayed through different means.

Figure 5 A flowchart showing the experimental procedure (see online version for colours)



One area of the virtual art gallery contains works in a three-dimensional rendered form that enclose the user within the work by mapping it onto the walls of several virtual buildings. In the Dark Luminance gallery environment, designers here use the artworks as textures and incorporate interactive elements allowing users to walk ‘into’ the paintings as part of a large art-park virtual environment. See Figure 6, the Dark Luminance exhibit (Dethridge, 2011), the second environment used for testing is a Wall Gallery, which presents the art works as would a traditional gallery. In this virtual environment, each work is framed and appears to be hanging on the virtual wall (Figure 6). Within these two test groups the order of presentation was split 50/50 to avoid a confounding variable related to presentation order.

Figure 6 The Wall Gallery and Dark Luminance virtual worlds used in the experiment (see online version for colours)



The scheduled timeline of each experimental test was as follows:

- completion of informed consent forms
- completion of pre-experimental questionnaire
- collection of *Affect Map* response
- experimental Trial 1
- collection of *Affect Map* response
- completion of post-trial questionnaire
- experimental Trial 2
- collection of *Affect Map* response
- completion of post-trial questionnaire
- completion of post-experimental questionnaire.

5 Results and analysis

After collecting data from the 24 participant trials and analysing it in statistical software (SPSS) several significant results were found. Notable correlations were found based on the viewing perspective used, the order in which the locations were visited, the participants gender, the number of hours spent per week in a virtual world and the combined score from the various questions designed to gather interest level of the users in visual art.

5.1 Viewing perspective (T-test)

When analysing the effects of viewing perspective on the user, multiple observations can be made. The 1st person perspective was positively correlated to increased ratings of engagement and immersion in the first trial regardless of location ($p = 0.003$ and 0.017 respectively).

In the Dark Luminance location, the 1st person perspective showed a similar effect however it did not reach a $p < 0.05$ or a less than 1/20 chance of being a type 1 error (significance was $p = 0.067$ for engagement and $p = 0.054$ for immersion). No statistically significant differences were found in the 3rd person perspective.

These results are summarised in Table 2 and Table 3. The difference in ratings of engagement and immersion between viewings of the Dark Luminance and those of the Wall Gallery may be due to one key factor. The Wall Gallery does not require as much interaction and viewing ‘dexterity’ as the Dark Luminance area. The art in the Wall Gallery is centralised and positioned at a consistent height which allows the user to keep a fixed camera angle. This simplicity could mediate against any potential advantages gained from the use of a 1st person perspective.

Table 2 Measures of engagement and immersion for the users related to viewing perspective

Perspective		*N*	*Mean*	*Std. deviation*	*Std. mean error*
Engagement (trial 1)	1st person	11	7.27	1.191	0.359
	3rd person	12	5.25	1.603	0.463
Immersion (trial 1)	1st person	11	7.27	1.104	0.333
	3rd person	12	5.17	2.480	0.716
Engagement (trial 2)	1st person	12	6.83	2.443	0.705
	3rd person	12	6.50	2.316	0.669
Immersion (trial 2)	1st person	12	6.17	2.552	0.737
	3rd person	12	5.75	2.832	0.818
Engagement (3D)	1st person	11	8.00	1.342	0.405
	3rd person	12	6.58	2.065	0.596
Immersion (3D)	1st person	11	7.55	1.572	0.474
	3rd person	12	5.75	2.491	0.719
Engagement (wall)	1st person	12	6.17	1.992	0.575
	3rd person	12	5.17	1.850	0.534
Immersion (wall)	1st person	12	5.92	2.151	0.621
	3rd person	12	5.17	2.823	0.815

Table 3 Measures of engagement and immersion T-test

		Independent samples test								
		Levene's test for equality of variances		*t-test for equality of means*						
									95 % confidence interval of the difference	
		F	*Sig.*	*T*	*Df*	*Sig. (2-tailed)*	*Mean difference*	*Std. error difference*	*Lower*	*Upper*
Engagement (trial 1)	Equal variances assumed	0.790	0.384	3.409	21	0.003	2.023	0.593	0.789	3.257
	Equal variances not assumed			3.454	20.187	0.002	2.023	0.586	0.802	3.244
Immersion (trial 1)	Equal variances assumed	13.263	0.002	2.587	21	0.017	2.106	0.814	0.413	3.799
	Equal variances not assumed			2.667	15.472	0.017	2.106	0.790	0.428	3.784
Engagement (trial 2)	Equal variances assumed	0.143	0.709	0.343	22	0.735	0.333	0.972	−1.682	2.349
	Equal variances not assumed			0.343	21.937	0.735	0.333	0.972	−1.682	2.349
Immersion (trial 2)	Equal variances assumed	0.292	0.595	0.379	22	0.709	0.417	1.101	−1.866	2.699
	Equal variances not assumed			0.379	21.766	0.709	0.417	1.101	−1.867	2.701
Engagement (3D)	Equal variances assumed	1.998	0.172	1.930	21	0.067	1.417	0.734	−0.110	2.943
	Equal variances not assumed			1.966	19.024	0.064	1.417	0.720	−0.091	2.924
Immersion (3D)	Equal variances assumed	3.222	0.087	2.044	21	0.054	1.795	0.878	−0.031	3.622
	Equal variances not assumed			2.085	18.746	0.051	1.795	0.861	−0.009	3.600
Engagement (wall)	Equal variances assumed	0.118	0.735	1.274	22	0.216	1.000	0.785	−0.628	2.628
	Equal variances not assumed			1.274	21.881	0.216	1.000	0.785	−0.628	2.628
Immersion (wall)	Equal variances assumed	2.684	0.116	0.732	22	0.472	.750	1.025	−1.375	2.875
	Equal variances not assumed			0.732	20.555	0.472	.750	1.025	−1.384	2.884

An alternative hypothesis is that the difference is related to how the user experiences the nature of the two locations. The Wall Gallery, consisting of framed static pictures, has already removed the user from the ‘actual’ active experience of exploring the objects first hand. Since the user is in a more passive viewing state rather than an active exploratory state, as they are in the Dark Luminance environment, the shift of perspective from a more realistic view (1st person) to an abstract view (3rd person) may detract less from the experience.

It is interesting to note that the measured means for both engagement and immersion were higher across all trials using a 1st person perspective. This correlates well with previous research (Bryce and Rutter, 2002; Schofield, 2011b) and gives a good indication that this perspective is potentially superior for creating immersion and engagement in a virtual art gallery setting.

5.2 Location and order (T-test)

There was a clear effect for the location itself on engagement and immersion. Effects relating to the order in which the participants visited the two locations were also found to be significant (Table 4 and Table 5).

We note a difference between the participants who saw the Wall Gallery prior to Dark Luminance and the other half who saw the Dark Luminance area prior to the Wall Gallery.

Table 4 Measures of engagement and immersion for the users related to location and order

Order		*N*	*Mean*	*Std. deviation*	*Std. mean error*
Engagement (trial 1)	DL/Wall	11	6.27	1.794	0.541
	Wall/DL	12	6.17	1.749	0.505
Immersion (trial 1)	DL/Wall	11	5.91	2.468	0.744
	Wall/DL	12	6.42	1.975	0.570
Engagement (trial 2)	DL/Wall	12	5.17	2.082	0.601
	Wall/DL	12	8.17	1.467	0.423
Immersion (trial 2)	DL/Wall	12	4.67	2.708	0.782
	Wall/DL	12	7.25	1.913	0.552
Engagement (3D)	DL/Wall	11	6.27	1.794	0.541
	Wall/DL	12	8.17	1.467	0.423
Immersion (3D)	DL/Wall	11	5.91	2.468	0.744
	Wall/DL	12	7.25	1.913	0.552
Engagement (wall)	DL/Wall	12	5.17	2.082	0.601
	Wall/DL	12	6.17	1.749	0.505
Immersion (wall)	DL/Wall	12	4.67	2.708	0.782
	Wall/DL	12	6.42	1.975	0.570

The data illustrates that both groups rated the first area they saw almost equally. The mean rating for Dark Luminance when seen in Trial 1 is an engagement measure of 6.27 and an immersion measure of 5.91, while the mean rating for the Wall Gallery when seen in Trial 1 is an engagement measure of 6.17 and immersion measure of 6.42. These scores show no significant difference ($p = 0.887$ for engagement and $p = 0.590$ for immersion).

Table 5 Measures of engagement and immersion T-test

		Independent samples test								
		Levene's test for equality of variances		*t-test for equality of means*						
		F	*Sig.*	*T*	*Df*	*Sig. (2-tailed)*	*Mean difference*	*Std. error difference*	*95 % confidence interval of the difference* Lower	*95 % confidence interval of the difference* Upper
Engagement (trial 1)	Equal variances assumed	0.004	0.950	0.143	21	0.887	0.106	0.739	–1.431	1.643
	Equal variances not assumed			0.143	20.720	0.887	0.106	0.740	–1.434	1.646
Immersion (trial 1)	Equal variances assumed	0.767	0.391	–0.547	21	0.590	0.508	0.928	–2.438	1.423
	Equal variances not assumed			–0.541	19.180	0.594	0.508	0.937	–2.468	1.453
Engagement (trial 2)	Equal variances assumed	1.523	0.230	–4.081	22	0.000	–3.000	0.735	–4.525	–1.475
	Equal variances not assumed			–4.081	19.763	0.001	–3.000	0.735	–4.535	–1.465
immersion (trial 2)	Equal variances assumed	2.675	0.116	–2.699	22	0.013	–2.583	0.957	–4.568	–0.598
	Equal variances not assumed			–2.699	19.789	0.014	–2.583	0.957	–4.581	–0.585
Engagement (3D)	Equal variances assumed	0.324	0.575	–2.782	21	0.011	–1.894	0.681	–3.310	0.478
	Equal variances not assumed			–2.757	19.392	0.012	–1.894	0.687	–3.330	0.458
Immersion (3D)	Equal variances assumed	0.790	0.384	–1.464	21	0.158	–1.341	0.916	–3.246	0.564
	Equal variances not assumed			–1.447	18.850	0.164	–1.341	0.927	–3.281	0.600
Engagement (wall)	Equal variances assumed	0.478	0.496	–1.274	22	0.216	–1.000	0.785	–2.628	0.628
	Equal variances not assumed			–1.274	21.367	0.216	–1.000	0.785	–2.631	0.631
Immersion (wall)	Equal variances assumed	2.526	0.126	–1.809	22	0.084	–1.750	0.968	–3.757	0.257
	Equal variances not assumed			–1.809	20.122	0.085	–1.750	0.968	–3.768	0.268

Significant differences were however found when the participants moved to Trial 2. Those who visited the Wall Gallery in Trial 2 gave it lower ratings of engagement (a measure of 5.17) and immersion (a measure of 4.67). Participants visiting Dark Luminance in Trial 2 gave it higher ratings of engagement (a measure of 8.17) and immersion (a measure of 7.25).

There is a high level of significance for the values measuring the differences between locations in Trial 2 ($p = 0.000$ for engagement and $p = 0.013$ for immersion).

When the differences in the location ratings of two groups who visited them in opposite order are compared the strongest effect is seen in the change in the engagement score for Dark Luminance which jumps from a measure of 6.27 in Trial 1 to 8.17 when measured in Trial 2. This effect is statistically significant ($p = 0.011$). None of the other analyses for location ratings between these two groups were significant (Table 5). Immersion in the Wall Gallery showed a small decreasing effect when viewed second (after the Dark Luminance environment). It is possible that more significant findings would appear with a larger sample size.

One explanation for the even ratings between the locations in the first trial is that perhaps the users have a predilection to remain neutral. This predilection may exist before a precedent for expectation has been set. The participants could be making judgments based on an abstract idea of engagement and immersion and once a precedent has been set, the scale may take on new meaning for them. It is possible that neither location offered a great ‘thrill’ to the users who simply rate the experience as slightly above neutral. The results may suggest that the trial fulfilled the descriptive needs of most participants as both locations were somewhat enjoyable.

The higher and lower ratings in the second trial can be explained simply because the Dark Luminance area is aesthetically more engaging and immersive relative to the Wall Gallery. Dark Luminance provides an open interactive experience which has previously been reported as being perceived by the user as more ‘fun’ than a static gallery (Dethridge, 2011). However, there could also be deeper causes at work. If the Wall Gallery puts the Dark Luminance images and artwork into the mind of the participant, this could then set expectations as to the content of the trials and what to expect from the art itself. When entering the Dark Luminance area the users encounter an unexpected transformation of the passive pictures into interactive models, buildings and displays. A similar thing happens when participants visit the Wall Gallery after seeing Dark Luminance. Instead of breathing life into static images, the Wall Gallery environment is perhaps seen to remove life from the artworks, leaving only static images behind.

Further studies could pair two sets of locations which differ in the same respect as the Wall Gallery and Dark Luminance. One location may contain the same virtual artworks and one may contain different artworks. These experiments would then measure whether the two sets of users experienced a significant difference in how the ratings change between the equivalent Wall Gallery area and the equivalent Dark Luminance area in each.

5.3 Gender (T-test)

No correlations to gender were found for either engagement or immersion. Gender was, however, found to have a significant relation to ratings of both control comfort and control naturalness (Table 6 and Table 7). The most powerful effects of this are seen in the ratings of control naturalness for Trial 2 which males rated at a mean of 7.90 and females rated at 5.57 (p = 0.004) and control naturalness for the Dark Luminance environment which males rated at 8.22 and females rated at 5.43 (p = 0.002).

A simple possible explanation for this difference is that demographically, previous research has shown that males are more likely to spend greater amounts of time playing computer and videogames than females. Males are therefore perhaps more used to the interface and more capable of exercising control within a virtual world when using a standard computer mouse and keyboard setup (Shashaani, 1997). Data supporting this explanation is illustrated clearly within the experimental results collected which showed a mean of 28.3 computer use hours per week for male participants while female participants showed a mean of 13.14 computer use hours per week (p = 0.013).

A further possibility for the differences in ratings between control naturalness and control comfort is that ‘comfort’ may have had physical associations while ‘naturalness’ could be seen by the users to apply directly to the straight-forwardness and intuitiveness of the control. The control may have been deemed comfortable while still requiring a period of learning meaning it perhaps still felt ‘unnatural’ (Hall and Cooper, 1991). Hence, if the ‘natural’ rating is deemed to connote familiarity, propriety or proficiency it is likely a demographic used to similar styles of control (in this case the males in the user group) would rate the control interface higher.

Additionally, a likely reason the effect of natural control is stronger in the Dark Luminance environment than in the Wall Gallery environment is that it requires increased dexterity of movement and therefore exaggerates differences in control capability. The Wall Gallery requires users only to view a narrow band of the vertical axis and navigation is made simple by virtue of the confined area.

Alternatively Dark Luminance allows for travel around and behind objects and requires the user to view much greater angular ranges both horizontally and vertically as well as allowing for interaction with some of the objects and images.

Table 6 Measures of comfort and naturalness for the users related to gender

Gender		*N*	*Mean*	*Std. deviation*	*Std. mean error*
Control comfort (Trial 1)	Male	9	7.44	1.944	0.648
	Female	14	6.29	2.091	0.559
Control naturalness (trial 1)	Male	9	7.78	2.224	0.741
	Female	14	5.86	2.107	0.563
Control comfort (Trial 2)	Male	10	8.10	1.449	0.458
	Female	14	6.50	2.175	0.581
Control naturalness (trial 2)	Male	10	7.90	1.449	0.458
	Female	14	5.57	1.950	0.521
Control comfort (wall)	Male	10	7.50	1.900	0.601
	Female	14	6.21	2.225	0.595
Control naturalness (wall)	Male	10	7.50	1.900	0.601
	Female	14	6.00	2.148	0.574
Control comfort (3D)	Male	9	8.11	1.453	0.484
	Female	14	6.57	2.027	0.542
Control naturalness (3D)	Male	9	8.22	1.716	0.572
	Female	14	5.43	1.869	0.500

Table 7 Measures of comfort and naturalness T-test

		Independent samples test								
		Levene's test for equality of variances		*t-test for equality of means*						
		F	*Sig.*	*T*	*Df*	*Sig. (2-tailed)*	*Mean difference*	*Std. error difference*	*95 % confidence interval of the difference* Lower	*Upper*
Control comfort (trial 1)	Equal variances assumed	0.000	0.995	1.332	21	0.197	1.159	0.870	–0.651	2.968
	Equal variances not assumed			1.354	18.152	0.192	1.159	0.856	–0.638	2.955
Control naturalness (trial 1)	Equal variances assumed	0.004	0.947	2.089	21	0.049	1.921	0.920	0.008	3.833
	Equal variances not assumed			2.063	16.515	0.055	1.921	0.931	–0.40	3.889
Control comfort (trial 2)	Equal variances assumed	1.239	0.278	2.021	22	0.056	1.500	0.792	–0.41	3.241
	Equal variances not assumed			2.162	21.940	0.042	1.500	0.740	0.065	3.135
Control naturalness (trial 2)	Equal variances assumed	1.826	0.190	3.191	22	0.004	2.329	0.730	0.815	3.842
	Equal variances not assumed			3.355	21.934	0.003	2.329	0.694	0.889	3.768
Control comfort (Wall)	Equal variances assumed	0.110	0.744	1.400	22	0.153	1.286	0.869	–0.516	3.087
	Equal variances not assumed			1.521	21.190	0.143	1.286	0.845	–0.471	3.043
Control naturalness (wall)	Equal variances assumed	0.456	0.507	1.767	22	0.091	1.500	0.849	–0.261	3.261
	Equal variances not assumed			1.805	20.884	0.086	1.500	0.831	–0.229	3.229
Control comfort (3D)	Equal variances assumed	0.779	0.388	1.869	21	0.062	1.540	0.782	–0.086	3.166
	Equal variances not assumed			2.119	20.650	0.046	1.540	0.727	0.027	3.053
Control naturalness (3D)	Equal variances assumed	0.294	0.593	3.608	21	0.002	2.794	0.774	1.183	4.404
	Equal variances not assumed			3.679	19.306	0.002	2.794	0.759	1.200	4.387

The small, not statistically significant, difference between male and female ratings of comfort seems to increase a little between Trial 1 and Trial 2. Perhaps the best explanation is that this is simply due to chance. There was one other significant gender difference (p = 0.022) in the ratings given to virtual world potential (the user's view of the potential of the technology as a means of viewing artworks). We can hypothesise that perhaps this was again related to the increased familiarity of male participants with computer technology.

5.4 Hours in virtual world (one way ANOVA)

There were no significant effects of note regarding the hours the users used a computer. However, there is a non-significant correlation between this score and immersion both in Trial 1 and in Dark Luminance with significance factors of p = 0.073 and p = 0.075 respectively. This does not offer a reliable conclusion as to whether more frequent use and experience within virtual worlds make experiences in the virtual art galleries seem more immersive (Figure 8).

Table 8 Measures of engagement and immersion ANOVA

Perspective		*Sum of squares*	*df*	*Mean square*	*F*	*Sig.*
Engagement (Trial 1)	Between groups	24.691	7	3.527	1.284	0.322
	Within groups	41.222	15	2.748		
	Total	65.913	22			
Immersion (trial 1)	Between groups	55.615	7	7.945	2.398	0.073
	Within groups	49.689	15	3.313		
	Total	105.304	22			
Engagement (trial 2)	Between groups	56.744	8	7.093	1.551	0.221
	Within groups	68.589	15	4.573		
	Total	125.333	22			
Immersion (trial 2)	Between groups	62.203	8	7.775	1.181	0.371
	Within groups	98.756	15	6.584		
	Total	160.958	22			
Engagement (wall)	Between groups	42.644	8	5.331	1.789	0.158
	Within groups	44.689	15	2.979		
	Total	87.333	23			
Immersion (wall)	Between groups	46.569	8	5.821	0.915	0.530
	Within groups	95.389	15	6.359		
	Total	141.958	23			
Engagement (3D)	Between groups	31.513	7	4.502	1.503	0.240
	Within groups	44.922	15	2.995		
	Total	76.435	22			
Immersion (3D)	Between groups	58.623	7	8.375	2.377	0.075
	Within groups	52.856	15	3.524		
	Total	111.478	22			

However, the metric is close enough to significance to indicate that this area could benefit from further study. One could hypothesise that participants who used virtual worlds less often would potentially find this experiment more immersive. Although, the opposite is suggested by the data (although it is non-conclusive). The possible causes of this result could be:

- That users who spend more time in virtual worlds (in particular three-dimensional game environments) do so because they have a disposition to find them more enjoyable.
- That frequent use of virtual worlds causes higher ratings as an affinity already exists with the technology.
- That feelings of immersion really do increase with more frequent use of similar technology.

5.5 Combined art score (one way ANOVA)

The combined art score was a combination of all of the data relating to the user's pre-existing appreciation, knowledge and interest in art from the pre-experimental questionnaire.

The categories comprised of art production, artists liked, interest in visual art, art work recognition, exhibit/gallery attendance and exhibit/gallery enjoyment. The combined art score was calculated by a direct summation as all were on the same scale and increasing values led to a greater appreciation of art in all cases.

Significant correlations were found to age and to academic year as well as to the user's perception of vividness and realism in the virtual galleries (Figure 9). No significant correlation existed with engagement or immersion, although there is evidence for a weak positive correlation to immersion in Trial 1 but stronger statistical power is needed to demonstrate significance in this result ($p = 0.087$).

A positive relation seems to exist between the combined art score with age and academic year which potentially shares the same cause.

One can hypothesise that age brings about greater knowledge, a greater fondness for art, and that older participants would show more enthusiasm for art due to their life experiences which would translate to higher scores on ratings of art enjoyment and the other responses used for the combined art score.

The participant's measured vividness ratings were significantly higher in both Trial 2 and in the Wall Gallery for participants with a higher combined art score ($p = 0.01$ and $p = 0.027$, respectively). The participant's measured realism ratings in the Wall Gallery were also significantly higher ($p = 0.038$). This could suggest either a parallel to the participant's real-life experience of visiting similar gallery/exhibit locations or that the participants have a greater willingness to experience the featured art in a virtual setting if they have greater experience of real-world art.

Table 9 Measures of age, academic year, vividness and realism ANOVA

		Sum of squares	*df*	*Mean square*	*F*	*Sig.*
Age	Between groups	654.958	16	40.935	17.909	0.000
	Within groups	16.000	7	2.286		
	Total	670.958	23			
Academic year	Between groups	36.625	16	2.289	4.006	0.035
	Within groups	4.000	7	.571		
	Total	40.625	23			
Realism (trial 1)	Between groups	120.609	16	7.538	2.827	0.103
	Within groups	16.000	6	2.667		
	Total	136.609	22			
Vividness (trial 1)	Between groups	73.457	16	4.591	2.900	0.097
	Within groups	9.500	6	1.583		
	Total	82.957	22			
Realism (trial 2)	Between groups	91.500	16	5.719	1.232	0.410
	Within groups	32.500	7	4.643		
	Total	124.000	23			
Vividness (trial 2)	Between groups	113.833	16	7.115	6.225	0.010
	Within groups	8.000	7	1.143		
	Total	121.833	23			
Realism (wall)	Between groups	120.125	16	7.508	3.893	0.038
	Within groups	13.500	7	1.929		
	Total	133.625	23			
Vividness (wall)	Between groups	100.958	16	6.310	4.417	0.027
	Within groups	10.000	7	1.429		
	Total	110.958	23			
Realism (3D)	Between groups	93.435	16	5.840	1.001	0.541
	Within groups	35.000	6	5.833		
	Total	128.435	22			
Vividness (3D)	Between groups	77.370	16	4.836	3.868	0.052
	Within groups	7.500	6	1.250		
	Total	84.870	22			
Enjoyment of visited art	Between groups	105.458	16	6.591	2.977	0.074
	Within groups	15.500	7	2.214		
	Total	120.958	23			
Preferred location	Between groups	3.500	16	.219	1.531	0.293
	Within groups	1.000	7	.143		
	Total	4.500	23			

6 Conclusions

This paper has described a series of experiments involving 24 participants who experienced virtual artworks in multiple gallery environments, utilising different viewing perspectives. A number of positive correlations regarding the user experience were made from an analysis of the results. These results have identified key factors or guidelines that are useful to those attempting to design or create their own online virtual art environments. It is interesting that the statistical work seems to back up general statements that one would, on first pass, think would be true about viewing virtual art.

- Engagement and immersion with the virtual experience can be increased by use of a 1st person perspective.
- The order in which different environments are experienced has a significant effect on the experience of the user.
- Increasing the amount of interaction will provide the user with a more engaging and immersive experience.
- Users who are more familiar with the technology, will be more comfortable in the virtual gallery environment.
- Users who have an existing appreciation of art will find the virtual artworks more stimulating (vivid and real).

This research work has attempted to explain a user's engagement with virtual art exhibits, which is dependent on such qualities of immersion. Following the insights provided by a number of theorists including Milgram and Kishino (1994), this project showed that increased engagement of the user can be achieved through an increase in the quality of graphics, interaction and content. This analysis of the experimental data has provided an insight into the components that make up an engaging and productive virtual art experience for the user. As Rose (2012) states regarding the use of immersive technology:

> "People have always wanted to in some way inhabit the stories that move them. The only real variable is whether technology gives them that opportunity."

According to Murray (1997), humans are somehow 'hardwired' to accept stories as reliable ways of understanding the world:

> "A stirring narrative in any medium can be experienced as virtual reality because our brains are programmed to tune into stories with an intensity that can obliterate the world around us... The experience of being transported to an elaborately simulated place is pleasurable in itself, regardless of the fantasy content. We refer to this experience as immersion. Immersion is a metaphorical term derived from the physical experience of being submerged in water. We seek the same feeling from psychologically immersive experience that we do from a plunge in the ocean or swimming pool: the sensation of being surrounded by a completely other reality, as different as water is from air, that takes over all of our attention, our whole perceptual apparatus…"

Designers of virtual tools and environments may note that immersion is defined as a state of consciousness where a user's awareness of their 'real' physical self is diminished within an engrossing graphic environment. This study suggests that engagement and interaction within artificial, virtual environments can provide the conditions where a user perceives themselves as a different kind of 'first-person' actor or presence in a non-physical world. The degree to which the virtual artistic environment faithfully reproduces reality helps to determine the degree to which a user may suspend their disbelief. The user's familiarity with the tools is also a factor in allowing their acceptance of the illusion as 'real'. Their engagement and levels of interaction will also be partly determined by the amount of interest they have in the world that is presented; by their motivation to explore and investigate the virtual terrain. It is ironic to note that we may use sophisticated digital tools to encourage a kind of regression into forms of 'magical' thinking. Certainly, these tools allow us to build models of reality; to test ideas and processes and to solve problems within those models.

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