Temporal and Spatial Coherence:
chronological and affective narrative within holographic and lenticular space.

A thesis submitted in partial fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Imaging and Displays Research Group

DE MONTFORT UNIVERSITY

Leicester, United Kingdom

By

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September 2018

Sponsored by the Department of Physics and Astronomy, University of Southampton.

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ACKNOWLEDGEMENTS

The University of Southampton: Thank you to my sponsors, the Department of Physics and Astronomy, and the Heads of Department who have financially supported my research: Professors Anne Tropper, Phil Charles, Peter De Groot (RIP), Tim Morris and Jonathan Flynn. Thank you too to my line-managers: Professors Nick Evans and Malcolm Coe for their support. Thank you to Dr Matt Himsworth, Dr Paul Gow, Alex Jantzen and Tom Jefferson-Brain for explaining various aspects of Physics to me – more than once. Thank you too to Dr Sadie Jones, for her encouragement and support. Thank you to Sadie and the colleagues who shared their research data with me: Professors Anthony Bird and Hans Fanghor and Drs Gaby Slavcheva, Elena Kammann, John Nesbitt, Anna Scaife, Matteo Franchin and Alexander Belyaev.

Thank you too to Outreach Directors of the South East Network (SEPnet): Clare Harvey and Drs Charlotte Thorley and Dominic Galliano for their support and encouragement.

De Montfort University: Thank you of course to my supervisors who have been an inspiration: Professor Martin Richardson (who has been helping me with holography over the last 30 years), Ernest Edmonds and Martin Reiser, and Benedict Carpenter (who rescued me when I wanted to give up at the last minute). Thank you to Jeremy Collingwood and Stuart Wade for their patient technical support. I am also grateful for the support of mentor artist/holographer Dr Isabel Azevedo and my fellow researchers, Sandra Oliveira (RIP) Yin-Ren Chang, Tove Dalenius, Vivian Amos and Amani Abed. Thank you too to Teodora Kuzmanova and Boris who hosted me when I stayed in Leicester.

Professional support: My thanks to Rob Luckins for photographing my work during *The Virtual Artist* Exhibition and Jon Mitton for his lenticular printing. Thank you too to Jani Frank and Mick Smith for mentoring me at the beginning of the process, Jeremy Turner for providing me with a Helium Neon (HeNe) laser when mine stopped lasing at a crucial time, and Stas Zacharovas and GEOLA for printing my digital hologram.

My family: Thank you to all those who gave me permission to use their photographs and heirlooms, particularly my Sister and Brother-in-law Michelle and Brian Gravett, and Father, Michael John.

Lastly, I would like to thank the holography community, including; Mike Medora and the late Professor Tung Jeong and Dr Margaret Benyon MBE, who invited me along on this journey when I was a teenager.

In memory of my Mother, Judith Alison John.

TEMPORAL AND SPATIAL COHERENCE: CHRONOLOGICAL AND AFFECTIVE NARRATIVE WITHIN HOLOGRAPHIC AND LENTICULAR SPACE.

ABSTRACT

The thesis for this practice-based study maintains that the Z and X axes of lenticular and holographic space can be used to store images chronologically, providing an audience with a new experience with affective and authentic impact. My contribution to knowledge has been to create a new element to the lenticular, analogue and digitally animated holographic artform. My research presents my family's archival material – photographs, film, text and objects – in a sequential order within the Z and X axes of holographic space, creating an animated four-dimensional (4-D) family album in which my ancestors recede into holographic space and members of the current generation float in front of the surface of the media. Audience experience of the artwork has been gathered and evaluated, providing evidence of the research study's contribution to knowledge.

Figure 1 *Great Grandmother*, reflection hologram and digital print, Pearl John, 2012

> *…longing to have such a memorial of every being dear to me in the world. It is not merely the likeness which is precious…but the association and the sense of nearness involved in the thing…the fact of the very shadow of the person lying there fixed forever! (*Barrett, 1843).

1 INTRODUCTION

Artists working with holography and lenticular imaging have been utilizing the four-dimensional (4-D) temporal and spatial characteristics of both media for creative and affective impact since the late 1960s and early 1970s (Benyon, 1968; Man Ray, 1971). However, those temporal and spatial characteristics of holographic time and space have not been used to depict a chronological narrative with affective impact.

My practice-based research work, aims to create a new element to the lenticular and holographic artform, by utilising holographic space to store images chronologically. My research presents family archival material – photographs, film, text and objects – within the Z and X axes of holographic space to depict different time periods. The work creates three-dimensional (3-D) and 4-D family albums in which my ancestors recede into holographic space while members of the current generation float in front of the surface of the medium. This use of a temporal geometry, particularly when used with family archival material, has an affective impact on audience members which has been evaluated in this study.

The research results in the creation of three distinct bodies of new holographic and lenticular artwork which answers the research question of whether the X and Z axes of holographic space can be used to represent a chronological perspective and have an emotional impact on the viewer. The different bodies of work are described in Table 1 below. Academic research outputs and research impact are described briefly below and can be found in the concluding chapter of the dissertation. The research topic has been considered timely and of interest to an international audience of holographers. This introduction consists of five key elements: first, an outline of the study's aims and outcomes, second, a concise statement of the research question; third, a definition of the scientific and creative terms used in the dissertation; fourth, an outline of the study's contribution to knowledge, including a description of the context for the research question; fifth, an introduction to the methodology used; and finally, a statement of the value of the research outcomes to an international audience of artists working with

holography, the main audience for the research. The research aims and outcomes are summarised below:

1.1 Research Objectives

The objectives of the research are as follows:

- To investigate whether the X and Z axes of holographic space can be used to create artwork with a chronological perspective
- To select and develop appropriate methods for determining the artwork's affective impact
- To understand the affective impact of the artwork on its audience (primarily other artists using holographic and lenticular media).

The anticipated outcomes for the research are as follows:

- The creation of an original body of artwork containing chronologically ordered imagery within holographic space
- The public exhibition of the work to provide an audience for the research
- An evaluation of evaluate audience experience of the work, determining its cognitive and affective impact.

1.1.1 Defining the research question

This section of the introduction defines the research question and the scientific terminology and concepts used in this dissertation. The study's research question asks:

Can temporal and spatial coherence be achieved in lenticular imaging and holography, to create a new element of the artform, and provide an audience with a new experience with affective and authentic impact?

While this practice-based research is primarily creative, it utilises technological imaging processes and scientific terminology and concepts. The imaging processes are described in Appendix I of this dissertation and the scientific terminology and concepts are detailed below.

1.1.2 Temporal and spatial coherence – a scientific explanation

While a detailed scientific and mathematical explanation of the terminology used in this dissertation is beyond the scope of this research, a broad explanation of the relevant terms which form the title of this dissertation follows. 'Coherence' relates to the property of laser light which makes holography possible and is defined in the *Penguin Dictionary of Physics* as:

> The degree to which electromagnetic radiation…maintains a near-constant phase relationship, both temporally and spatially. (Cullerne, 2000, p.62).

Light travels in waves; sunlight and artificial light are made up of many different wavelengths or colours, and are therefore not coherent. Laser light, which is required to make holograms, is coherent: it is highly monochromatic; the light waves emerging from the laser are the same wavelength or colour; and the waves are all of the same amplitude or height (the amplitude relates to the brightness of the light). If the waves are identical in height and width, or the same brightness and colour, then the laser light is coherent. This is referred to as being 'in phase', or 'in antiphase' (Wenyon, 1978, p.15) as shown in the diagram below:

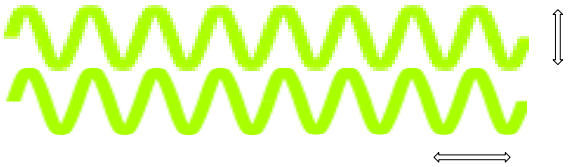

Figure 2. Illustration of laser light waves in phase

The height of the wave from top to bottom, or peak to trough, is known as the amplitude of the wave and is responsible for the brightness of the wave.

Wavelength is the distance from peak to peak or trough to trough.

Coherence has three properties: waves are in phase, as shown above in figure 2, and the light is spatially and temporally coherent (Saxby, 2004). While laser light is theoretically in phase, there is a difference in the theory and practice of the production of laser light; in practice, the laser beam can lose coherence temporally, along its length; and spatially, across the width of the beam (Semertzidis, 2005). This loss of coherence affects the laser's ability to produce a hologram, which relies on the laser beam remaining in phase.

1.1.3 A hologram

The late holographer Graham Saxby, describes a hologram as follows:

> …to the physicist, a hologram is a record of the interaction of two mutually coherent light beams, in the form of a microscopic pattern of interference fringes. To the well-informed lay person, it is a photographic film or plate that has been exposed to laser light and processed so that when illuminated appropriately it produces a three-dimensional image. (2004, p.3).

Holographers have to ensure that they use specific geometries for their holographic camera set-up, taking temporal coherence lengths into account in order to produce clear, bright holograms. The geometries of the holographic projects undertaken during the course of this research are described in Appendix I of this dissertation.

1.1.4 Temporal coherence: a creative explanation

While the terms temporal and spatial coherence relate to the scientific process which creates holograms using laser light, the terms are used in this thesis primarily to explain creative and metaphorical concepts. Temporal and spatial coherence are used here to describe 3-D and 4-D images whose narrative is chronologically ordered within lenticular or holographic space.

The contemporary French-Canadian artist Jacques Desbiens first used the term 'temporal incoherence' in *Experiments in image composition for synthetic holography* at the Eighth International Symposium on Display Holography, held in China in 2009 (ISDH2009). He describes digital holography as a medium which produces temporally incoherent images, distorting linear narrative. Desbien argues that there are three different aspects which impact the synthetic hologram's image: reversibility, time smear and doubling.[1] When a viewer moves from side to side in front of an animated lenticular or holographic image, a film will play forwards and backwards, playing and reversing the narrative.

> Reversibility can create some logical contradictions or modification of meaning…The represented time can only be a collection of events,

[1] These technical aspects are inherent in my work and described in Chapter Five, the results section of this dissertation.

> synchronised in space, but narration may not be chronological anymore. (Desbien, 2009, p.175).

Artists using animated lenticular images, analogue stereograms, and digital holograms have creatively used incoherence resulting from reversibility (Randazzo, 1991; Nakamura, 1999; Boyd, 2017). Works by all of these artists depict figures running backwards and forwards, their movements controlled by the movement of the viewer. The emotional impact is used for different effects: sometimes the reversibility emphasises loss and triggers nostalgia, and sometimes, as in the case of Boyd's work, the aspect is used for comic effect. Other artists have used lenticular images and holograms in which the narrative retains its coherence despite the reversibility of the image (Robb, 1993; Ohlmann, 2007; Mrongovius, 2009[2]). These artists depict a repetitive image which makes narrative sense when the image is run forwards or backwards. The impact of these repetitive artworks is soothing, amusing and exciting the viewer. These artworks are illustrated and discussed further in Chapter Two.

Invoking Desbiens's use of the term 'temporal incoherence' to include a reference to images which do not make narrative sense when the animation is run forwards and backwards, I argue that images which *do* make narrative sense when run forwards and backwards could be considered to have an aspect of 'temporal coherence'. My use of the terminology, then, is more metaphorical than it is scientific or technical. What is missing from Desbien's work is the consideration of chronological narration using both the Z and X axes of lenticular and holographic space.

1.1.5 A coherent temporal and spatial narrative

My thesis argues that the depth of holographic or lenticular space, can be used to represent time in a coherent, chronological narrative. I propose that an animated image is temporarily and spatially coherent if the Z and X axes in the 3-D image, are used to represent passing time. To explain this simply: the further back in holographic and

[2] Not all animated images are designed to change along the X axis: see, e.g., *Jumping Jellies* (Mrongovius, 2009) illustrated in figure 15, a white light transmission stereogram which shows an animation of a jelly fish. The movement is vertically activated as the viewer jumps up and down on a trampette, changing their viewing angle and the viewed image.

lenticular virtual space that the image sits in relation to the viewer; the further back in chronological time the narrative lies. In this research, I provide an illustration of the concepts of 'deep time' and/or 'distant memory', adding space to time and memory. This use of holographic space incorporates the position of the viewer within the artwork. As the artwork is interactive the viewer as integral to the artwork (Candy, 2004). The audience for the artwork is described further in section 1.2.3 of this dissertation; however, there are still concepts used in this project which need to be defined, such as the concepts of time and space, and holographic space, which are central to the research. These aspects are described below.

1.1.6 The Holographic Principle

The concepts of space, time, and different dimensions are becoming increasingly complex: in current research in theoretical physics and mathematics, there are arguments variously suggesting that there are five, ten, eleven, twenty-six, or an almost infinite number of dimensions of space, and none of them use the fourth dimension to represent time as we experience it. In *Radical Dimensions*, scientist Margaret Wertheim describes how a 'dimension' has become a mathematical construct, not part of the material world:

> General relativity paints a picture of a four-dimensional universe, and string theory says it has 10 dimensions – or 11 if you take an extended version known as M-Theory. There are variations of the theory in 26 dimensions, and recently pure mathematicians have been…describing spaces of 24 dimensions. (Wertheim, 2018).

The 'Holographic Principle' is a concept in theoretical physics and it is not related to the practical application of holography. While the studies of mathematics and physics are outside the scope of this research, the terminology does deserve a brief explanation as this research project is so rooted in the metaphorical application of space and time within holographic imaging.

The Holographic Principle is an analogy of a mathematical concept proposed by Professors Gerard t'Hooft and Leonard Susskind in 1993 and studied by Professor Kostas Skenderis and the University of Southampton's Theory and Astronomy Group (STAG), where I work as the Public Engagement Officer for Physics and Astronomy. Skenderis described the Holographic Principle, and the development of the physics which led to it,

in his Inaugural Lecture entitled; *The Holographic Principle* (Skenderis, 2013). The principle states that "the information contained within a region of space can be determined by the information at the surface that contains it" (ibid). The principle comes from the mathematics of black holes research, which explains how information about the entire black hole can be determined from the area of the black hole's event horizon, rather than the volume of the black hole.

The Holographic Principle no longer uses the fourth dimension to represent time as we live it. In an interview with a physicist from the University of Southampton, Dr Matthew Himsworth describes how the concept of time was theorised by Albert Einstein in his 'Special Theory of Relativity', proposed in the early 1900s. In Einstein's theory, 'Time' was no longer the absolute concept as described by Newtonian physics: it became another dimension, but one intrinsically linked with space (Himsworth, 2018). In the 1915 theory of General Relativity, spacetime became a fundamental object (Skenderis, 2013). My research in effect illustrates an element of the spacetime continuum. The research visually merges three dimensions of space and one dimension of time into a 4-D continuum, so images are depicted in sequence in the Z axis of holographic space.

Although concepts of different dimensions are fascinating, this thesis uses the term three-dimensional to describe a spatial image (Okoshi, 1976), and four-dimensional to describe an image with temporal and spatial aspects. This concept of four dimensions, rather than five plus dimensions, has been employed here as it describes the felt, human experience of space and passing time.

1.1.7 Holographic space

In 1989, artist Andrew Pepper defined holographic space, graphically shown below in figure 4. Holographic images can be positioned in the following ways: behind the holographic plate; projected in front of the plate; or straddling the image plane, the surface of the holographic plate (1989, p. 298).

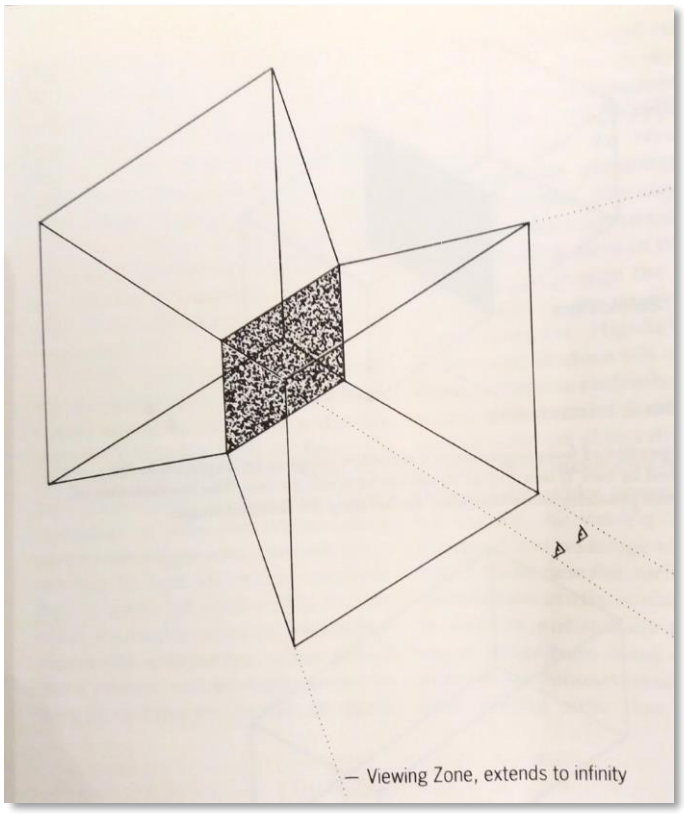

Figure 3. Illustration of *A graphic definition of holographic space*, Andrew Pepper, *Leonardo*, 1989.

The shaded area in the above illustration depicts the surface of the holographic plate, or film, and is known as the image plane. The area closest to the viewer's eyes relates to an area which in a real image can be projected in front of the holographic plate, and the area behind the plate refers to the volume of space behind the plane of the hologram which can contain a virtual image (Benyon, 1994).

This definition of holographic space omits the dimension of time. In physics, time and space are inextricably linked. This study argues that time can be included in a description of holographic space, and that an opportunity exists to use different areas of holographic space to depict different time periods. My research has included the use of lenticulars, analogue and digital holograms, which have incorporated virtual and real images in holographic space, to represent different time periods in space and create an affective geometry.

The concept of holographic space applies to lenticular imaging too; however, the lenticular image is far more limited in its use. Holography can store a great deal more information than lenticular imaging, and therefore has access to a greater amount of depth both behind and in front of the image plane. Different types of holograms also differ in their access to holographic space, laser transmission holograms depicting the greatest amount of depth, and digital holograms the least, because of the way that the images are made (Schröter, 2014).

1.1.8 Authenticity

Because I argue that the fourth dimension relates to our felt experience of time, the last aspect of this study's research question asks whether adding depth to a sequence of chronologically ordered images creates an affective, authentic experience for the viewer. Authenticity in this context refers both to an attempt to present a more accurate representation of the human experience of time and space, and to the concept of the paradoxical nature of the aura in original and copied artwork, as described by the Weimar philosopher Walter Benjamin in his 1931; *Little History of Photography*:

> The here and now of the original underlies the concept of its authenticity. (Benjamin, 2008a, pp.21-22).

And in a different translated version; *Small History of Photography*:

> What is aura actually? A peculiar weave of space and time: the singular appearance only of distance, however close it may be. (Benjamin, 2015, p.82).

1.2 The Contribution to Knowledge and Research Context

The study's contribution to knowledge is a new element of the lenticular and holographic artform. My research has resulted in the creation of artworks with temporal and spatial coherence, with authenticity and affective impact. The artwork utilises both the X and the Z axes of holographic space to represent a temporal geometry, and places images in a coherent, chronological narrative in holographic space. This novel application of the X and Z axes can be described as a new element of the lenticular and holographic artform,

expanding the aesthetic vocabulary of the media. This use of holographic space, which incorporates the position of the viewer within the conceptual frame of holographic space and time can be perceived by an audience of holographic art experts, and has a demonstrable emotional impact on viewers; it is described in detail in Chapter Five.

The context, or contexts, for this study are both academic and societal, and include the five following aspects: firstly and most importantly, the aesthetic development of the art medium of holography; secondly the rise of the Art Science movement; thirdly the concept of authenticity; fourthly the current academic research environment; and lastly the influence of two aspects of contemporary culture – methods of retaining family history, and methods of transmitting emotional content in social media. Chapter Two of this dissertation includes a thorough state-of-the-art review, incorporating a survey of both the relevant literature and the artwork which form the background to this research topic, explaining the above concepts in greater detail.

1.2.1 The art medium of holography

> '"Virtuality artists" …distinguish themselves through their techno-aesthetic creative commitment" (Popper, 2007, p.1).

In the last decade, the production of digital animated holograms by companies such as Rabbit Holes[3], Zebra Imaging[4] and the General Optics Laboratory[5] (GEOLA Digital UAB), along with developments in lenticular imaging software, such as Virtua 3-D[5], have provided artists with new tools with which to create their work, resulting in an expansion in the aesthetic vocabulary of holographic art. Holography has been used as an art medium since the late 1960s (Benyon, 1967; Nauman, 1968) and according to the art historian and critic Frank Popper and holographers (Benyon, 1985; Zec, 1989; Dawson, 2011) its aesthetic vocabulary is constantly undergoing advances as a result of technical innovation. (Popper, 1993).

[3] RabbitHoles Media Inc. Canadian digital holography company (Bjelkhagen, 2013, p.509)
[4] Zebra Imaging Inc., USA. Producers of *Digital Head*, Martin Richardson.
[5] GEOLA Digital UAB. The Lithuanian-based digital holography company has produced holograms for Dietmar Olmann (2009), Paula Dawson (2007), Martin Richardson (2010), Isabel Azevedo and myself.

Digital animated holograms can now be designed in full colour using commercial 3-D model-making software (*Cinema4D*, *3-D Studio Max*), then printed remotely by holographic production businesses. In the past, artists have had to produce analogue holograms with lasers in purpose-built labs. The state of the art review in Chapter Two outlines the most pertinent elements of the development of the holographic aesthetic vocabulary by those artists who provided the foundation to the analogue holography art medium, such as: Benyon, 1967; Berkhout, 1979; Boisonnet, 1989; Boyd, 1996; Kaufman, 1994 and Wenyon and Gamble, 1986.

In *The Art of Colour Holography (Pioneers in Change)* SPIE conference paper artist and academic Martin Richardson declares that:

> Digital technology is changing holography. It is liberating those who make a living from the medium from the restrictions of their 18th century darkrooms. (2000, p.274).

These technological advancements, which release artists from the darkrooms, will be described fully in the second chapter of this dissertation, the state-of-the-art review (Dawson, 2009; Desbiens, 2009; Richardson, 2009; Azevedo, 2011) who exhibited artwork and presented papers in over the last decade at the *HoloExpo* 2011 (in Minsk, Belarus), and at the *International Symposia on Display Holography* (2010, 2013, 2015, and 2018). The dissertation also describes the impact of artists working

Technological developments in holography, from analogue to digital, have been a motivating factor in this research. The author shares the above artists' interest in temporal and spatial concepts, but has answered the problem by using holographic space in a new way and involving an audience in the research study.

1.2.2 Contemporary art and the art science movement

The beginnings of the art and technology movement have been widely debated. In her Ph.D. dissertation, Paula Dawson, the pioneering Australian artist working with large format holography, quotes Jonathan Benthall, who argues that the movement began in the early 1960s when art was called upon to humanise technology:

> Great hopes have been expressed about the reuniting of art with science and technology. It has been convincingly argued that there is a need for a comprehensive approach to human experience. (1972, p.11).

However, in *Art of the Electronic Age*, Popper claims that the origins of technological art can be traced to the industrial revolution (1993). This argument is further discussed in Chapter Two of this dissertation.

The work of early artists working with technology has evolved into the movement within contemporary art, art science. This movement is acting in collaboration with public engagement with scientific research, enabling art to be used to engage the public with research and to ensure the public's continuing support for science. In *Art and Science Now,* a contemporary overview, Stephen Wilson writes:

> Science-related arts are seen as useful in making information come alive for general audiences. (2010, p.15).

As the Public Engagement Leader in Physics and Astronomy at the University of Southampton, my role is to encourage scientists to work with artists to engage the public with their research, as this is seen as good practice (IOP, 2015). This situation, combined with the growth of the contemporary art science movement, provided a context for this research study. This background led to my questioning what visual scientific representational systems were in place to illustrate the passage of time, and formed a background to the study's research question. Another important aspect of the research was the role of the public in research, and that aspect is described next.

1.2.3 The role of the audience in research

This section discusses the role that the audience has in the research, and includes the current academic environment with relation to Research England's Research Excellence Framework (REF). The REF rewards academic units for research that has had an impact outside academia; outreach and public engagement are recognised as societal impact. The medium of holography is very popular with the general public, and group shows attract large audiences. Throughout the period of the research study, I have exhibited my artwork in group shows. The *Holographic World Exhibition* which accompanied the *HoloExpo* 2011 drew approximately 100,000 visitors to the National Academy of Sciences of

Belarus in Minsk, with further large audience numbers reached through the television and media coverage (Belarussian Telegraph Agency, 2012). In 2012, the time-themed lenticular images produced in the first element of the research project were exhibited to more than 10,000 visitors at the *Royal Society Summer Science Exhibition* in London and, more recently, the number of visitors to *The Magic of Light* exhibition in St Petersburg and Moscow (2015-2016) exceeded 85,000. The number of visitors, and interest shown in the exhibition by the media, indicates that this general topic of research was, and still is, relevant and timely to the general public.

While the numbers of visitors and ticket sales are impressive, there was no qualitative data gathered to determine the audience's experience of the holography, or the artworks exhibited. My professional role includes gathering audience feedback to determine their experience of all the activities we offer to engage the public with our research. The role has demanded I care about the audience experience, as the public pay for scientific research and universities need the public's support to ensure further funding. In the context of that professional demand, I felt uncomfortable with a lack of qualitative evaluation of audience experience of my artwork during the large-scale shows in which I took part. As an artist, on the other hand, I was trained to dismiss the importance of the general public's opinion of my own artwork, because of the time lag that it takes for new concepts and modes of delivery to be considered acceptable by society. It has though been argued recently that the public's opinion is becoming more valued in the art world. In *Playing to the Gallery*, the Turner Prize-winning artist Grayson Perry writes:

> The circle of artist, museum, critic dealer and collector did not necessarily need the good opinion of the public. Now I think that it's different, and that popularity may affect the course of art history. (2014, pp. 4-5).

Perry argues that because museums rely on footfall in order to keep them running, being popular is important for artists.

Evaluating the audience experience of my work has provided a context for the research, not only because of the influence of the REF, but because of the importance of the role of the viewer in the study: it is the viewer who creates the three- and four-dimensional artworks by their movement in front of the pieces. The experience of three different

audiences was gathered during the course of the research: the general public; a small focus group of professional artists; and a group of international experts in art and holography. Different groups were chosen because familiarity with the media was shown to influence audience perception of the artwork. Some artists unfamiliar with holography had difficulty in comprehending and perceiving the cognitive aspects of the holographic artworks (one professional artist who took part in a pilot focus group had difficulty distinguishing between a hologram and a lenticular); however, those unfamiliar with the medium were more forthcoming in declaring the emotive impact of the work. As a result of the experience with the pilot evaluation, I chose to show the work to an audience of experts in holographic art, my peers, in order to confirm that the concept of temporal and spatial coherence was communicable, and to determine the affective impact of the research. The methods used in evaluating the artworks are described in Chapter Three of this dissertation.

1.2.4 The viewer

This section of the introduction explains why the spectator is an important part of the research and is influenced by the work of Linda Candy (2007): the viewer creates the three- and four-dimensional images manufactured in this study through their physical movement enabling them to view the 3-D and 4-D animated images; and the viewer conceptually creates the temporal and spatial coherent image through their physical positioning in relation to the medium and the content of the artwork. Finally, the research question asks whether the artwork provides an audience with a new experience.

The explanation of how an animated hologram is viewed by an audience member has been touched upon in the earlier explanation of the research question; someone has to move left-to-right and right-to-left to view a temporally coherent or incoherent animated image (when animated along the X axis). Without the movement of the viewer, the image cannot move or be perceived. This means that their participation is a vital element of the artwork itself. Also, the concept of temporal and spatial coherence depends on the viewer being physically positioned in front of the artwork, and on their perception of the depth of the image within holographic space. It is important here to note that holographic space

also includes the space projected in front of the hologram. Again, the participation of the viewer is crucial in in creating and experiencing the artwork.

1.2.5 The affective impact of authenticity

This section describes why temporal and spatial coherence is important: not only can it be perceived and understood by the viewer, but it has an affective impact, adding authenticity to the artwork. This impact is described in detail in Chapter Five.

The elements that create affective impact, including authenticity, are as follows: firstly, the physical impact that viewing the lenticular and holographic images has on the audience; secondly, the effect that the image content has on the viewer; thirdly, the auratic nature of holographic images; and lastly, the effect of indexicality. John Berger in *Understanding a Photograph*, first published in 1967, explains how appearances in photographs 'cohere':

> To recognise an appearance requires the memory of other appearances…as soon as we say that appearances *cohere* this *coherence* proposes a unity not unlike that of a language. (2013, p.84).

So, it can be argued that there is a coherence, or connection, formed in the mind of the viewer between the images that they view and their own mental images, which helps create an emotive response to viewing the artwork produced in this study. The appropriated images I have used in my research include my own family's photographs and belongings. Because of the process of coherence described by Berger, my family's images become shared, or universally recognisable, rather than purely personal.

The next relevant aspect of photography involves the purpose of photographs and their meaning. American writer and filmmaker Susan Sontag, describes the temporal and spatial purposes of photography:

> To take a photograph is to participate in another person's (or thing's) mortality, vulnerability, mutability. Precisely by slicing out this moment and freezing it, all photographs testify to time's relentless melt. (1977, p.15).

Sontag also writes, “Photographs…help people to take possession of a space in which they are insecure”. (1977, p.9). For Sontag, emotions relating to photographs and photography involve vulnerability and insecurity in relation to capturing time and space. These emotions are also present in our responses to holograms and holography based on photographic images. Holograms have much in common with photography and yet have an extra dimension which, it can be argued, captures experience more authentically than a photograph. The impact of images is enhanced by the virtual space within holograms and lenticulars, and the added element of animation. The hologram both freezes time and expands it. An animated hologram can re-enliven the image of a person and add emotional impact, in a similar manner to a film. Sontag, again in *On Photography* (1977), argues that time adds affect when photographs are presented as a slide show:

> Both the order and the time for looking at each photograph are imposed; and there is a gain in visual legibility and emotional impact. (1977, p.5).

It is for this reason that this study includes animation in both lenticular and holographic images.

There is also a paradoxical nature to the media used in the research; photographs and images contained within the works are both tantalisingly close and yet unobtainable within virtual space, and can therefore be described as auratic. This is a concept defined by Walter Benjamin (2008) and defined above in section 1.1.6. The aura of the original photographs in the holographic images is arguably still present, despite the fact that the artworks contain copies of photographic images. This paradox has an impact on the viewer, observed and described in Chapter Five.

Turning to the concept of indexicality, it can be argued that the artworks have been impacted by the photons of the original light which touched the subjects imaged, and this aspect adds to the authenticity of the artwork. Amelia Jones, in *Critical Terms for Art History*, describes the importance of the portrait in the development of photography:

> Being an indexical trace of the body before the camera, then, the photograph promised to return the represented body to some kind of authentic state… in some incontrovertibly “real” way. (In Nelson, 1996, p.257).

These different aspects of photographic and holographic media are shown to have an emotional impact on the viewer in this study.

1.2.6 Contemporary society

The elements of contemporary society which provide context for this research include the emergence of the digital family tree and the use of social media to maintain connections between people. These aspects are described below.

Two contemporary methods of displaying the family tree are relevant to my research study. The first is the computer software programme Ancestry.com, and the second is the use, by the artist Matthew Andrews, of lenticular imaging to display family photographs. The physical family photographic album is becoming a thing of the past as society moves from analogue data storage to digital; the need for a digital means of retaining family histories and displaying them is growing. Historically, Sontag argues, photography became important as the nuclear family broke away from extended families:

> Those ghostly traces, photographs, supply the token presence of the dispersed relatives. A family's photograph album is generally about the extended family – and, often, is all that remains of it. (1977, p.9).

The author's own family has, like many others, been dispersed through global migration and the loss of our matriarchs, who kept the extended family together. Our efforts to maintain connections have been made through Facebook (Facebook.com). As the physical family photographic album has disappeared, it has been replaced to a great extent by social media, in particular Facebook, and we, along with two billion others (Fiegerman, 2017), have begun to store, display and share our photographic images with a much wider audience than family photographs were ever previously shared.

Another attempt to hold onto the extended family has been the creation of online family trees, using family tree software Ancestry.com (Ancestry.com), which, according to *The Guardian* in 2012, had two million subscribers world-wide (Sweney, 2015). The Ancestry.co.uk advertisements (VCCP Partners, 2013) depict a box on a coffee table,

which when opened contains the names of family, photographs receding into the depth of the box (figure 4).[6]

Figure 4 Screen grab of the Ancestry.co.uk TV advertising campaign

Another method of depicting the family albums has been made by the artists Miggs Boroughs and Matthew Andrews. Both artists have animated family photographs, depicting the same person aging over time. Andrews's business *Story Portrait* (www.storyportrait.co.uk) transfers analogue photographs to digital, and then produces animated lenticulars from them. Boroughs has produced animated images of his own family members. Both Boroughs and Andrews produce temporally incoherent lenticulars that animate from right-to-left and left-to-right, with the subjects aging and becoming more youthful again, the lenticular keeping a record of personhood over time. Neither Boroughs nor Andrews use the depth of lenticular space to represent different time periods as I have done in this research study.

[6] The concept used in this television advertising campaign - depicting different time periods within the Z axis of virtual space - is similar to my own concept using the Z axis in holography and lenticular imaging. However, my concept was presented at the *HoloExpo* 2011 (John, 2011), before the Ancestry.com advertising campaign began and my work also uses animated images and photographs in space while the advertisement does not.

Social media provides context for this study too. While digital communications systems such as texting and emailing add to the speed and ease of communication, these media are weak in terms of their ability to communicate emotional content. This weakness is mitigated by the use of animated images such as the gif (Giff.com) or, historically, Vine (Twitter, 2013) a discontinued video hosting service for short looped videos. Most recently, Boomerang from Instagram (Facebook, 2010) and Stories (Facebook, 2017), allow short video clips of temporally incoherent narratives, which run backwards and forwards, to be uploaded and shared with followers. These services have been created is because adding time increases the emotional impact of the photograph as described by Sontag above. (1977, p.5).

These short, filmed or drawn, animations have much in common with the short animations provided by lenticular imaging and animated holography, as they are short clips of emotionally impactful images. Describing animated images as temporarily coherent or incoherent provides contemporary society with new appropriate vocabulary.

My contribution to knowledge then is the creation of a new holographic and lenticular artform which defines a new conceptual use of virtual space, using the Z axis of the image to represent a chronological perspective. I have superimposed images within the perceived depth of the holographic space, images which make narrative sense in time, using the theme of the family album. The context for the research includes contemporary artists' use of the media, and contemporary society's use of family trees in digital form and social media. The next section will explain that viewing the artworks produced in this study, and comprehending how time and space have been depicted in them, has provided a specific audience with a new experience, both cognitively and affectively. This next section will describe how the audience was chosen for the study.

1.3 Methodological Approach

This study employs a practice-based methodology. Despite the scientific and technical nature of the artworks produced in the study and the scientific and technical vocabulary

used to describe certain aspects of the study, the research questions asked and answered in the study are creative and conceptual and do not solve scientific or engineering problems[7]. The third chapter in this dissertation defines and describes the practice-based methodology used in this study, referencing the research of artists Tine Bech (2014), Brigid Costello (2009) and Martina Mrongovius (2011), all of whom have used similar approaches to the one taken in this dissertation.

The research methods used have included: visualisation; creation of artworks; documentation; reflection and analysis; refinement; exhibition and observation. The research process has been iterative. Gray and Malins have described the role of the researcher in this methodological approach as being three-fold:

- a generator of the research material-art/design works, and participant in the creative process
- a self-observer through reflection on action and in action, and through discussion with others
- an observer of others for placing the research in context and gaining other perspectives. (Gray, 1988, p.21).

Answering the research question in this study necessitated the involvement of participants and evaluation of audience experience of the artwork. The methods used to determine audience experience included the consideration of ethical concerns around involving participants in the research process; the production and distribution of questionnaires; gaining audience feedback through critique groups; transcription of group discussions; and coding, theming and analysing responses as part of a process of evaluation. The methodological approach, and rationale for its use, is described in Chapter Three.

1.4. Foundation Work

Chapter Four describes the foundation work undertaken during my Master of Arts degree and the professional practice which informed my research topic.

[7] Technical explanations, where required, will be found in the Appendices of the dissertation.

1.5. Results

The research resulted in three distinct projects as follows: firstly, an investigation is made into representations of different time periods using lenticular images; secondly, the representation of a holographic family tree time-line in a gallery space is explored; and lastly, the creation of digital animated holographic and lenticular works is paired with a study of audience experience of the works. The table below lists and describes the different projects undertaken with their corresponding outputs.

1.5.1 Exhibited artworks

First, the body of lenticular artwork explored how different time periods have been illustrated using a scientific visual language. Time periods from very short durations to very long timescales were researched and illustrated. The creation of this first body of work was funded by the South East Physics Network (SEPnet) who helped arrange the exhibition of the work at the Royal Society Summer Show. Secondly, a body of analogue holograms were created to determine how to embed virtual space within two and three-dimensional objects, in this case found or archival objects, and to explore how the placing of holographic artworks within an exhibition space can represent a time-line to an audience. This creation and exhibition of this work was funded and supported by the Department of Physics and Astronomy at the University of Southampton. Thirdly, a digital hologram which embodied the concept of temporal and spatial coherence with affective impact was produced and exhibited to a small audience of artists and experts in the field of art holography. The data produced by capturing audience experience was analysed and evaluated. A summary of the outputs and exhibitions is presented below in Table 1.

Table 1. Research outputs and exhibitions

Project Phase	Description	Output	Exhibition
Phase 1: Representations of Time	Representations of scientific time periods using lenticular imaging	8 animated lenticular art works, (various sizes) 2012.	*In Time* exhibit at *The Royal Society Summer Science Exhibition*, London, UK. 03.07.12-08.07 12J.
Phase 2: The 3-D Family Album	An installation of 2-D and 3-D objects and analogue reflection holograms depict a family time line.	10 analogue reflection holograms, (various sizes) 2014.	*The Virtual Artist* Solo exhibition at the Special Collections Gallery, University of Southampton, UK. 26.08.14-26.09.14
		1 reflection hologram exhibited in group exhibition.	*The Magic of Light*, State Optical Museum, Saint Petersburg 01.07.15-10.11.15 & Saltykov-Chertkov Mansion, Moscow 10.02.16-29.05.16.
Phase 3: The 4-D Family album	Chronological narrative in time and space.	Digital animated hologram, 65cm x 25cm, 2018.	*Art in Holography: Light, Space & Time*. City Museum, Aveiro, Portugal. 26/06/18-30/09/18.

1.5.2 Publications

The timeliness and relevance of the project are evidenced by the publications and presentations given during the course of the research. Three papers resulting from the research process were written and presented orally to international audiences at holography conferences[8]. The first paper, *From Analogue to Digital: Fine Art in a New Medium* (2011), was given at the *HoloExpo* 2011, Minsk, Belarus. The invitation to contribute to the conference was made by Programme Committee Member Stanislav Zacharovas, Director of GEOLA, Vilnius, Lithuania, and travel and accommodation costs were funded by the conference. The topic of the author's research specifically was considered timely and of interest by the organisers of this international conference. The

[8] A fourth abstract was accepted for ISDH2015 at MIT, USA, but the paper had to be withdrawn and attendance at the symposium cancelled as a result of family health issues.

author also exhibited artwork at the group show supporting *HoloExpo* 2011 at the Belarus Academy of Sciences, which had 70,000 visitors[9] in the two months the show was open.

The lenticulars and holographic artworks have been exhibited to the public nationally and internationally at the following exhibitions: *Royal Society Summer Science Exhibition*, London, 2012; *Magic of Light*, St. Petersburg and Moscow, 2015-2017; and *Art in Holography: Light, Space & Time*, City Museum, Aveiro, Portugal. Two further research papers were given at ISDH2015 and ISDH2018. The impact of the research outside academia is discussed in the concluding chapter of this dissertation.

1.6 Outline of Thesis Chapters

The next chapters will describe the following aspects: Chapter Two will contain a thorough state-of-the-art review to provide a context for the research work; Chapter Three will describe the methodological approach for the study; Chapter Four will introduce the foundation work for the research; it is a short chapter describing previous work during my Masters studies and my professional practice which led to the development of my research question. Chapter Five will outline the results of the research and describe the artwork produced; Chapter Six will provide an analysis of the artwork and the evaluation of audience experience; what was learned from the results of the audience evaluation and the artworks themselves. Chapter Seven concludes the dissertation, confirming the contribution to knowledge which has been made. This chapter also describes the impact and significance of the research, and restates the research outputs (exhibitions and publications). Finally, I describe what research needs to be done next as a result of this study.

1.7 Summary

The introduction to this dissertation has covered five aspects of the research. Firstly, a thorough description of the research question has been given, which includes definitions of the relevant terminology and most importantly, the metaphorical use of the scientific terms of temporal and spatial coherence. Secondly, it has stated the contribution to

[9] http://www.holography.by/en/infocentre/news/2011/359/

knowledge that the research delivers; that of a new holographic and lenticular artform which uses the Z axis of virtual space to represent a chronologically ordered narrative. Thirdly, the research question has been explained, including how the artwork is shown to have an affective impact on the audience. I also described the main work which gave rise to the research question and its significance. Fourthly, I have outlined the methodological approach used to solve the research question. I have listed and described the research outputs and finally, I have provided an outline of chapter contents. The following chapter will provide a context for the research.

Table 2. Outline of thesis chapters

Outline of Thesis Chapters		
#	**TITLE**	**DESCRIPTION**
1	INTRODUCTION	
2	STATE-OF-THE-ART REVIEW:	This chapter covers the background of the use of holography as an art medium and the development of its aesthetic vocabulary; the use of colour, time and animation, space, lighting, a mixed media approach, the hologram as an object and the role of the audience. A description of the ways in which my research advances the development of medium and creates a new holographic artform.
3.	METHODOLOGY:	This chapter includes a justification for practice-based research and qualitative social science methods; a summary of the research process undertaken; the methods used to create the artwork; and a description of the methods used to gather and evaluate audience response.
4	FOUNDATION WORK:	A short chapter describing previous work during my Masters studies and my professional practice which led to the development of my research question.
5	RESULTS:	A description of the artwork produced during the course of the research.
6	ANALYSIS:	What was learned from the results of the audience evaluation and the artworks themselves.
7	CONCLUSION/S:	A review/answer to the research question/s; a description of the research impact and significance of the work and an assertion of the contribution to knowledge and a restatement of the research outputs (exhibitions and publications). What next – future research.
8	REFERENCES	
9.	APPENDICES:	Includes a description of the ethics code and procedures; technical terms/holographic and lenticular jargon. Exhibition audience questionnaire samples and sample observation sheets.

2 STATE-OF-THE-ART REVIEW

This chapter presents a survey and critical review of the written and creative research of authors and artists working affectively with photographic, lenticular imaging and holographic artwork to address temporal and spatial concerns with authenticity and affect.

The survey is based on primary sources including: dissertations; published papers; catalogues of exhibitions; and first-hand experience of exhibition visits and reviews; however, some text books have been referred to where the history of the scientific and technological aspects of photography, lenticular and holographic media are well-established. The review scrutinises and analyses how the technological and aesthetic evolution of photographic media has expanded from two to three and four dimensions, providing a historical and theoretical context to this study

This chapter describes the creative development of lenticular and holographic art media, providing a new, structured view of the field and giving a context to the ways in which my research advances the development of the aesthetic language of both lenticular imaging and holography; providing a contribution to knowledge.

The Chapter is divided into sections which review the work done by artists in two-, three- and four dimensions, exploring the ways in which holographic time, or times, and holographic space, or spaces have been utilized for emotional impact on the viewer.

2.1 The Two-Dimensional Image

The affective impact of a contemporary interactive artwork includes its ability to move people, both physically and emotionally. Lenticular and holographic imaging have the ability to move people physically, and to impact them emotionally. The affective impact of the media is rooted in early portrait photography and is inextricably linked to evoking the concept of memory and the feelings of nostalgia and loss. Walter Benjamin writes:

> It is no accident that the portrait was the focal point of early photography. The cult of remembrance of loved ones absent or dead, offers a last refuge for the cult value of the picture. (1931, p.219).

By reproducing images, photographs appear to capture time through the indexical nature of the technology. The writer Roland Barthes explained photography thus:

> The photograph is literally an emanation of the referent. From a real body, which was there, proceed radiations which ultimately touch me, who am here; the duration of the transmission is insignificant, the photograph of the missing being, as Sontag says, will touch me like the delayed rays of a star. (1980, pp.80-81).

Figure 5. Great Grandmother, Photograph from the John family archive, circa 1880.

From a scientific aspect the photons that hit the subject during a photographic exposure are absorbed by the subject, and faithful copies of the photon are emitted by that subject

reflecting onto the photographic paper. At an atomic level the photograph does indeed capture ‘an emanation of the referent’; the photograph records the wavelength and amplitude of the light that has reflected off the subject. The authenticity of the image and the aura that Benjamin describes (1931) have been caught through the action of reflected colour and light intensity on a silver halide paper. The next sections will discuss how artists have used the medium of holography with three and four dimensions, and the impact on the viewer of artworks depicting different aspects of time and space.

2.2 The Three-Dimensional Image

The review of lenticular and holographic images begins with the ways in which artists have used time and space with affective impact to engage their audiences. This section will discuss the early works of artists use of holographic time which contains multiple time periods within 3-D holographic images. The artist’s work discussed include: Margaret Benyon, the first artist to use holography, Bruce Nauman, and Paula Dawson. These artists have, metaphorically and creatively recreated time; freezing time, expanding time, and reversing time within the lenticular and holographic image.

2.2.1 Holographic time

Margaret Benyon was the first artist to use holography in 1967. As an Op artist and painter, Benyon was attracted to holography because of the scientific theories of light and perception which produced 3-D images: time; space; the structure of holographic space; and the artwork’s interaction with audiences. Her first hologram Interference Pattern Box (1967), shown below in figure 7, explored moiré patterns, referencing the interference patterns created by laser light which produced the holographic image (Benyon, 1981). Integral to the concept of interference is temporal and spatial coherence; the interference pattern which produces a hologram can only be produced by coherent light waves. The holographic image in the Interference Pattern Box sits behind the image plane, contained within virtual holographic space. Benyon describes it as follows: The subject of this hologram is a graphic kinetic interference pattern. An aspect of the holographic process

which is invisible in reconstruction is presented, that is the interference principle itself. The subject mirrors the process. (Benyon, 1981, p.35).

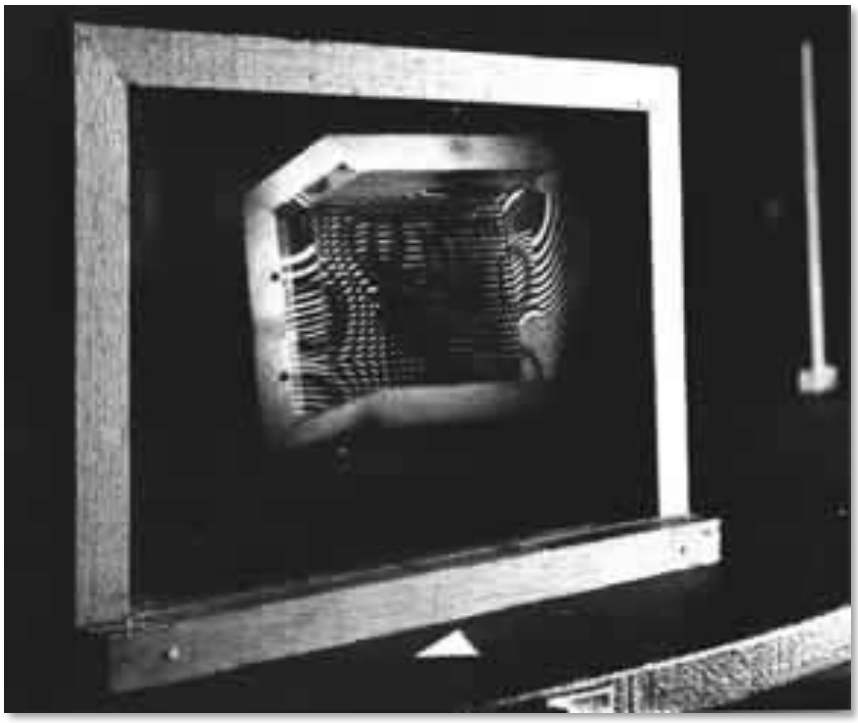

Figure 6. *Interference Pattern Box*, laser transmission hologram, 12.7cm x 17.8cm, Margaret Benyon, 1967.

The image recreates the time during which the image was captured. There was an affective aspect to this early work in that it necessitated the viewer's movement to create the animated moiré effect, and Benyon was concerned with how it was perceived by its audience. Viewing holographic works of art relies on the viewer's ability to both see and perceive the image and this has proved problematic. Benyon considered her first art holography exhibition unsuccessful; she observed the audience at the exhibition and noted their confusion and the discomfort they experienced from looking at her art.

> 'I thought I could continue in holography the preoccupations as a painter which led me into it. I quickly discovered after the failure of my first show in 1969 that I could not do this and that I should have to go back to square one…' (BENYON, 1981in JOHNSTON, 2006, p.318).

Benyon adapted the content of her artwork and began to include images of domestic scenes in order to connect with her audience so they could comprehend what they were seeing in the new medium. Op art had developed a new participatory relationship between viewer and artwork and this had impacted Benyon's practice;

> 'A natural predecessor to virtual art, op art drew attention to the spectator's individual, constructive and changing perceptions – and thus called on the attitude of the spectator to increasingly transfer the creative act onto themselves.' (Popper, 2007, p.110).

The medium of holography can appear to freeze time, expand time, and contain multiple time periods within single or multiple images if animated. These different aspects of the medium have an affective impact on the viewer and are discussed below.

2.2.2 Freezing and expanding time

Bruce Nauman experimented with holography a year after Benyon.[10] Both artists produced laser transmission holograms which needed to be illuminated with lasers in order to be seen by the audience, and both artists explored temporal and spatial aspects of holography; Nauman froze the body in time with his awkward self-portraits *Making Faces* (Davis, 1973, p.82). Nauman's work was the first example of a holographic portrait. According to Kenneth Baker's Review in *Artforum* the work has great affective impact, connecting with the viewer:

> We have an immediate sense of what it would feel like to distort one's face in those ways, and…we feel somewhat mocked by having faces made at us. (Baker, 1971, quoted in PLASKER, 2003).

Nauman's hologram both freezes the image and in doing so appears to expand time. In 1992, Martin Richardson explained it thus:

> …anyone who has had his portrait made holographically is being perpetuated. (Richardson, 1992, p.445).

[10] Both Margaret Benyon and Bruce Nauman exhibited holographic works in 1969 in the UK and USA (Benyon, 1996; Davis, 1973, p.82). Nauman used holographers to produce his artwork; Benyon made the holograms herself.

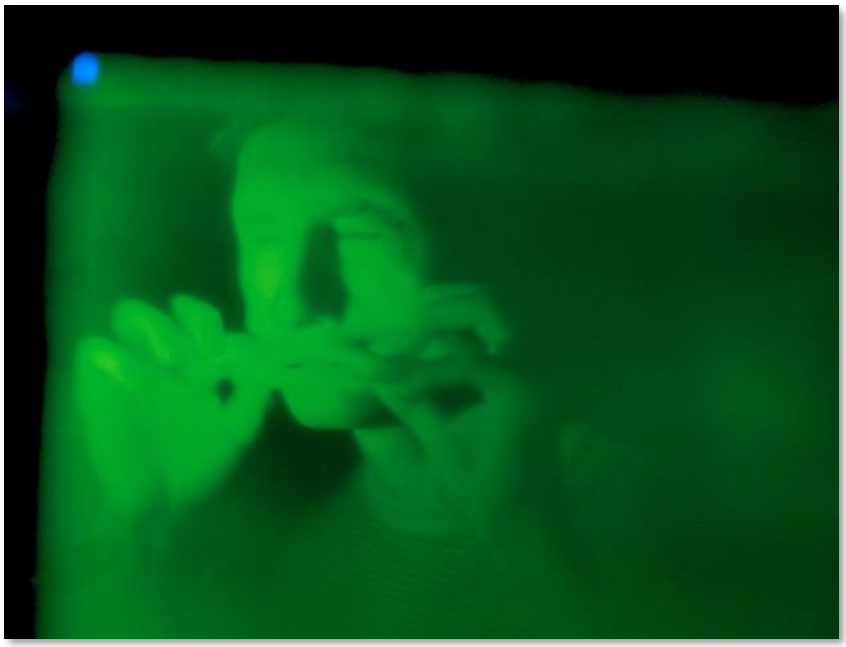

Figure 7. *Making Faces*, laser transmission, pulsed portrait, (size unknown) Bruce Nauman, 1968.

Holography is a medium which captures the phase of the wave. Richardson notes that with ruby pulse portraiture, the wavelength of light used to create the portrait passes through the first layer of skin; the photons that are emitted from the skin in the form of reflected light are produced at atomic level from faithful copies of the photons that hit the object. The holographic emulsion is able to capture the phase of the returned wave. That is information about time. The hologram records time, not just information about amplitude and wavelength. Now we have greater authenticity in the image that has been produced. The holographic art object is also not mass produced.

The faces that Nauman makes in his hologram have affective impact and they are uncomfortable to watch, especially knowing how dangerous the process of sitting for the portrait was. Nauman's eyes are closed, not just to draw the viewer's attention to the act of seeing, but also because the pulsed laser would have been too bright to look at without blinding himself.

2.2.3 Holographic times

The medium of holography not only has the ability to appear to freeze and expand time, but also to contain multiple time periods within single exposures.

Paula Dawson's triptych *To Absent Friends* (1989), illustrates how holography can be used to illustrate multiple time periods, even in works which contain a single exposure. The artwork consists of three laser transmission holograms which document an actual New Year's Eve party in a virtual bar she had constructed inside a warehouse, marking the moment that the clock struck midnight. Dawson explains how a laser transmission hologram can appear to contain different times;

> ...the [hologram] has unique temporal and spatial properties which can suggest a plurality of tenses. (Dawson, 1999, p.1)

The time periods depicted include the narrative of the party in full-flow at three different times in the evening; the duration of the exposure of the holograms; and the viewer's time as they engage with the artwork.

Figure 8. *To Absent Friends*, one of three laser transmission holograms, 150cm x 95cm, Paula Dawson, 1989.

Dawson (1999) argues that viewing a large hologram allows the viewer to become aware of the present time, noticing:

> a correspondence between his/her body movement and the view of the image, thereby contributing significantly to the viewer's perception of the image as existing at the same time as observation. (Dawson, 1999).

Artist Isabel Azevedo, describes the holographic artwork as performative, incorporating the different time which include the time during which the artwork has been conceived, created, and viewed. (Azevedo, 2014).

However, images have not yet been structured within the Z axis of holographic space to store images chronologically to create a coherent narrative. It is this missing element which has provided the author with a research problem. The next section describes ways in which holographic space has been used by artists.

2.2.4 Holographic space

Dawson describes holographic media as having a representational system very different to other forms of imaging (2011). Lenticular imaging offers a similar system, but with a more limited ability to represent time and space. I will use the term 'holographic' space when referring to both mediums. Both mediums represent three-dimensional space via a two-dimensional plane and do not use perspective systems to create illusions of depth. Holographic space includes the viewing zone, an optical cut-off point determined during the making of the image (Dawson, 1999) which is an important aspect of holography's representational system ignored by theorists Jean Baudrillard (1994) and Umberto Eco (1986), both of whom reviewed a science fiction version of holography, rather than the actual medium, making their commentary on the medium unhelpful when discussing authenticity (Dawson, 1999; Mrongovius, 2014).

There are other spaces, external to the lenticular or hologram, which are part of the artwork. There is the physical space that the artwork occupies and the manner in which it is displayed to an audience. There is also an affective space, the psychological space the artwork occupies as it impacts the viewer as the result of its interactive and affective nature. Since the 1970's many artists working with 3-D holography (Benyon, 1970, 1980; Pepper, 1989; Wenyon and Gamble, 1998) have produced artwork which demonstrates an interest in different aspects of holographic space. These different spaces, as described

by Pepper in his generalised graphic definition of holographic space (Pepper, 1989, p.298), consist of the virtual the space inside the hologram, the surface of the holographic plate and the area of the image which intrudes on the audience's space. This section describes the main ways in which artists working with holography and lenticular imaging use space, both practically and conceptually.

2.2.5 The space behind the plate

In *Non Hologram of Hand and Hot Air* (1970), illustrated below in figure 9, the hologram depicts a three-dimensional black hole in the shape of a hand against a lit background. In the foreground is a jug and a mug with steam emanating from it. Any movement during an exposure results in dark areas in the hologram. Benyon describes the work as a 'non-hologram', a virtual space captured within its own virtual space (Benyon, 1973). The work emphasises 'the presence of absence'.

Figure 9. *Non Hologram of Hand and Hot Air*, laser illuminated transmission hologram, 20.3cm x 25.4 cm, Margaret Benyon, 1970.

Figure 10. *The Cutter Index: Buha - Bullo, Dolly - Domestic Abuse*, holograms, Wenyon & Gamble, 2016.

Wenyon and Gamble's work on the other hand uses the space behind the holographic plate to emphasise the inaccessibility of the medium. Their work *The Cutter Index* (1998) illustrated in figure 10 above, depicts a Denisyuk hologram of a library index card drawer, containing information that the viewer is denied access to by the surface of the holographic plate.

2.2.6 Holographic spaces

Holographic space can also hold different volumes in the same space to create spatial montages and different views of the same object from different positions. These aspects of holographic space, or spaces, were explored by Margaret Benyon (1969), Salvador Dali (1969), Rudie Berkhout (1979) and John Kaufman (1994) and described below.

Benyon and Dali both referenced Picasso's painting *Les Demoiselles d'Avignon* (1907) in their holographic artwork pieces entitled *Picasso* (Benyon, 1969) and *Submarine Girl* (Dali, 1971). Benyon claims:

> The aim of the Cubists to record three dimensions on a two-dimensional surface is automatically achieved within holography. (Benyon, 1980 p.10).

My own work incorporates multiple spaces within the Z and X axes of the animated hologram through the inclusion of photographs layered within and structured in holographic space.

Figure 12. *Picasso*, laser transmission hologram, 32cm x 25cm, Margaret Benyon, 1969.

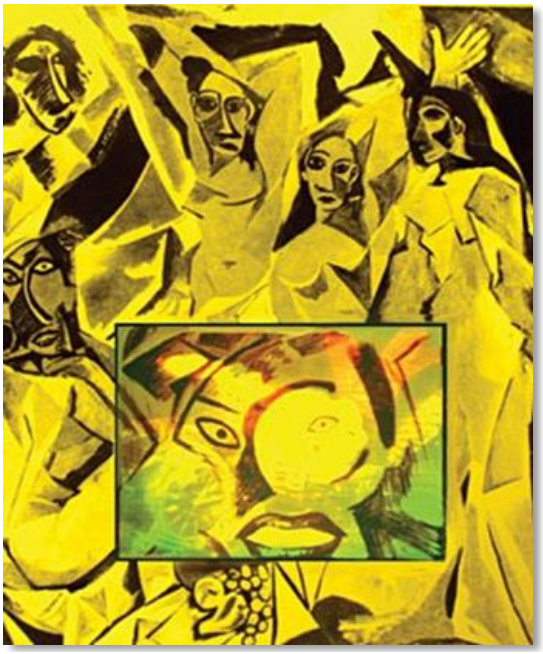

Figure 13. *Submarine Fisherman*, mixed media with 25.4cm x 20.3cm hologram, Salvador Dali, 1971.

Artists such as Rudie Berkhout (1979) and John Kaufman (1994), worked with objects real and virtual, which overlapped in space. Berkhout's abstract light shapes and colours occupied the same volume of space emphasising the immaterial nature of light and Kaufman's work emphasised the paradoxical nature of holographic immateriality working with beautifully coloured rocks. Both artists placed the objects of the artwork floating in a black background of space reminiscent of actual astronomical space. Their work is scale-less. Kaufman's rocks could be earth-bound, or asteroids.

2.2.7 The image plane

In 1974, Richard Hamilton produced a lenticular self-portrait entitled Palindrome, shown below in figure 14. Despite the title making a reference to the medium's ability to produce temporally coherent images with the word palindrome (which suggests the same meaning spelt out forward and backward), the artwork emphasises the spatial aspect of the medium, drawing the viewer's attention both to the surface of the lenticular image and the space in front of the image plane. Years later, Benyon collaborated with Hamilton to work with the surface of the holographic image, in a similar manner as he had done with the lenticular.

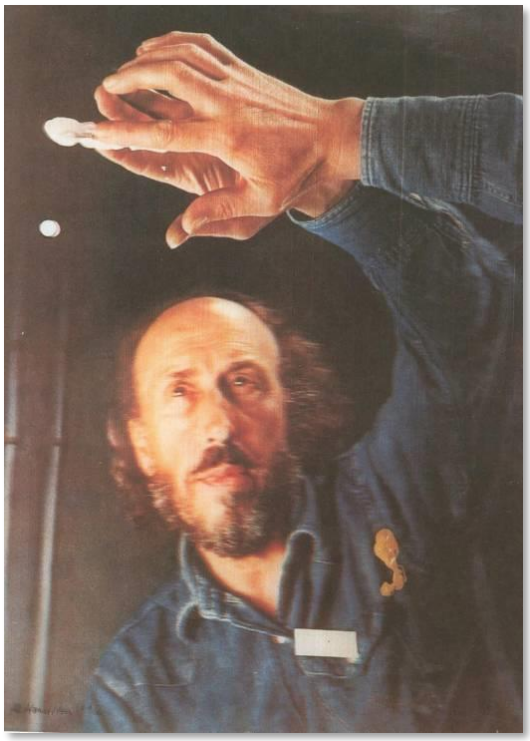

Figure 14. *Palindrome*, lenticular artwork, 30 x 40 cm, Richard Hamilton, 1974.
Figure 15. *Cosmetic Series: The Artist Richard Hamilton*, reflection hologram, 40cm x 40cm, Margaret Benyon, 1991.

2.2.8 The audience's space

The artwork which intrudes on the audience's space includes three different aspects of 3-D holography and lenticular imaging; the first includes images which escape the plane of the surface of the lenticular or hologram as depicted above in the work by Hamilton, (1974) and Benyon (1991) the second is the pseudoscopic image, and the last is installation work in which the space which includes the viewer as part of the artwork. These different aspects are described below:

Pseudoscopic space

In 1970, Benyon explored the new space available in the medium in front of the plate. In pieces such as *Clock, Mirror and Hypercube* (1970), Benyon utilises pseudoscopic space, the projected real image outside the surface of the hologram which appears between the plate and the viewer. Benyon flips the holographic plate to show a real image, inside out and in front of the plate. Viewing and understanding a holographic image relies on three

different aspects: the ability to see; to perceive the image; and to move to activate an animated hologram. Benyon's audiences were unable to comprehend the holograms that she produced which related to her understanding of space and time.

Figure 16. *Clock, Mirror and Hypercube*, laser transmission hologram, 25.4cm x 20.3cm, Margaret Benyon, 1970.

The pseudoscopic space of the Z axis of a real hologram is particularly confusing to comprehend. Holographer Michael Benyon explains it as follows:

> Pseudoscopy refers to the effect caused by moving one's head from side to side while viewing the real image; objects in the background of a scene appear to move more than those in front. The effect can be surprising and disconcerting when first encountered since it is contrary to the parallax effect observed in everyday life. (1978, p.68).

This disorientating aspect to Benyon's artwork must have strongly impacted the viewer seeing holograms for the first time, Benyon decided to reproduce more familiar imagery after her first show, concerned that it wasn't successful (1973).

Installation

The installation work of artists Christian Boltanski (1990), Wenyon and Gamble (1998) and Harriet Casdin-Silver (2001) is described below in relation to representations of holographic time and space with affective impact

Christian Boltanski's artwork provides a backdrop to the work of artists using photography, holography and lenticular imaging. For the viewer, engaging with Boltanski's work is similar to the physical experience of viewing lenticular or animated holographic artworks and installations. To view Boltanski's *The Reserve of Dead Swiss* (1990), which is a mixed media piece featuring forty-two framed photographic portraits of people of different genders and ages, requires that the viewer walk along parallel to the artwork to see the series of photographs. This locative motion echoes the manner of viewing a long, animated lenticular artwork or holograms exhibited in an installation such as Wenyon and Gamble's *Bibliomancy* (1989) shown below in figures 17 and 18.

Boltanski's work has tremendous affective impact. The portraits are lit with lightbulbs which are aimed into the centre of the portraits. The lights intrude on the portraits, obscuring the faces of the sitters. The lighting of the image is a necessary part of the piece, in a similar way to the manner in which the lighting of the hologram has been included within the holographic artwork by some holographers (Boyd, 1996; Boissonett, 1997). The photographic portraits are themselves blurred obscuring the identity and individuality of the sitter; in effect dehumanised. This evokes an ominous feeling in the viewer and a concern that those depicted have been interrogated, or tortured, with a light shone in their faces.

Wenyon and Gamble's work produced nine years later, has some similar elements to Boltanski's; the viewer moves along a wall-mounted series of carefully lit images with the lighting an important part of the installation, however the work, has a different affective impact (the subject matter being very different). The lighting of the piece provides a subdued atmosphere reminiscent of the atmosphere of the library from which the books were reproduced.

The artwork is fascinating and frustrating for the viewer as the books are tantalizingly realistic, but their contents inaccessible. Wenyon and Gamble's work juxtaposes outdated data storage systems captured with technology which cannot access the data.

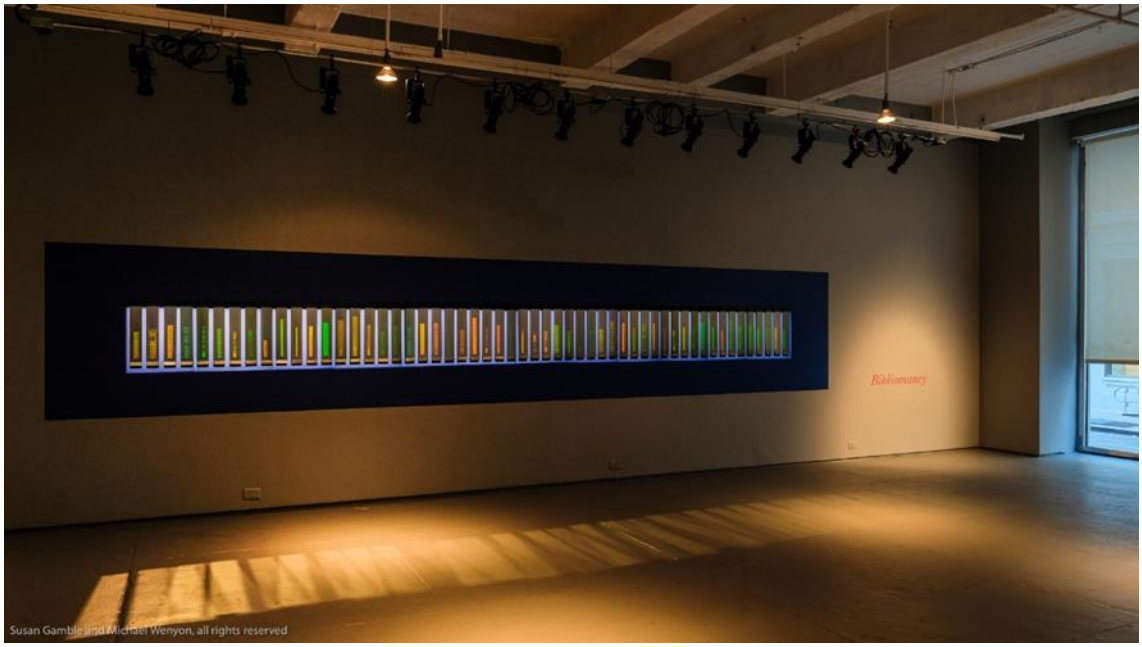

Figure 17. *Bibliomancy*. Reflection hologram installation, Magnan Metz Gallery 2016, Wenyon and Gamble, 1998.

Figure 18. *Bibliomancy*, reflection hologram installation, Magnan Metz Gallery 2016, Wenyon and Gamble, 1998.

Casdin-Silver's installation work *A Celebration of Aging*, shown in the Naga Gallery in Boston (2001) and described by critic A.D.Coleman, as a multimedia time capsule on multiple levels (2003), consisted of a series of nine large format white light transmission holographic portraits and audio sound domes. Standing under a sound dome enabled the audience member to both view the enlarged holographic portrait of a person in their 80s or 90s, and listen to that person narrate their life story. The personal histories included a gay man talking about what it was like to be homosexual in Boston before the second world war and the homophobia he had faced at that time. And there were also talking portraits of people who were Jewish, Asian and African American talking about lessening anti-Semitism and racism over the course of the century and their lives. The installation took the audience member on an emotional journey which ended optimistically.

2.3 The Four-Dimensional Image

When a three-dimensional image is animated and the viewer, or the artwork moves, the image can be said to be four-dimensional as the dimension of time has been added. This technical aspect expands the aesthetic vocabulary of holography and lenticular imaging enabling artists to represent time and space in different ways, with different affective impacts. The following artists artworks which explore representations of time and space and affective impact are discussed in this section; May Ray (1971), Lloyd Cross and Pam Brazier (1973, 1976), John Wood (1982) and Martina Mrongovius (2009).

2.3.1 Time in 4-D

The first artist to use the temporal properties of movement in lenticular imaging was Man Ray in his *Perpetual Motif* (1971), illustrated below in figure 19. The sculpture incorporated a lenticular winking eye mounted on the arm of a metronome to comic and surreal affect.

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Figure 19. *Perpetual Motif*, Metronome with lenticular eye, 22cm, Man Ray, 1971.

When the viewer has to move to animate an image however, they are more engaged with the artwork; they create the four-dimensional image with their movement, no longer merely a spectator, but more of a co-creator. The image can now be described as interactive.

To put the interactive element of holography into historical context, Popper argues that:

> interactivity has become an important theme in all branches of high technology art. It has a history, not only because of its use in "happenings", "actions", but also in optical and kinetic manifestations conceived by such artists as Agam or the Group de Recherche d'Art Visuel de Paris'. (Popper, 1995, p.7).

Figure 20. *The Kiss II*, cylindrical multiplex hologram, Lloyd Cross and Pam Brazier, 1976.

With interactivity comes an extension of the time periods contained in the artwork. This extra dimension is evident in the work of physicist Lloyd Cross, who invented the cylindrical animated hologram, known as the multiplex, or Integral hologram in 1973. Cross worked with artist Pam Brazier, to use the new type of holograms, to create The Kiss (1973), and later Kiss II (1976), illustrated in figure 20 above. The work featured an animated performance of Brazier blowing the viewer a kiss. Cross referred to the performance in an article in Leonardo as communicating 'a space-time event' (1992). Multiple time periods were captured in the work; the time during the shooting of the video and the replay of the image either through the movement of the cylinder the hologram was mounted on with a motor, or by the viewer walking around the hologram.

In 1982 artist John Wood, created a flat animated hologram of scissors opening and closing, and a teapot, featuring 80 different images a couple of views of which are shown overleaf in figure 21. The work was painstaking in a similar way to stop-motion animation, and it is evident that the making process itself can be said to contain an aspect of performance adding another time period to those captured within the hologram and experienced by the movement of the viewer in reanimating the four-dimensional image.

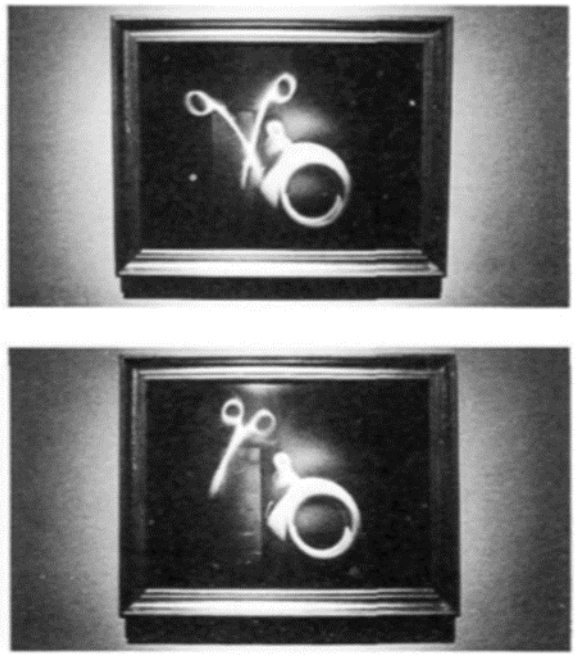


Figure 21. *Scissors and Teapot*, animated hologram, 30cm x 40cm, John Wood, 1982.

Martina Mrongovius describes an audience's physical engagement with her animated artworks as having an affective impact:

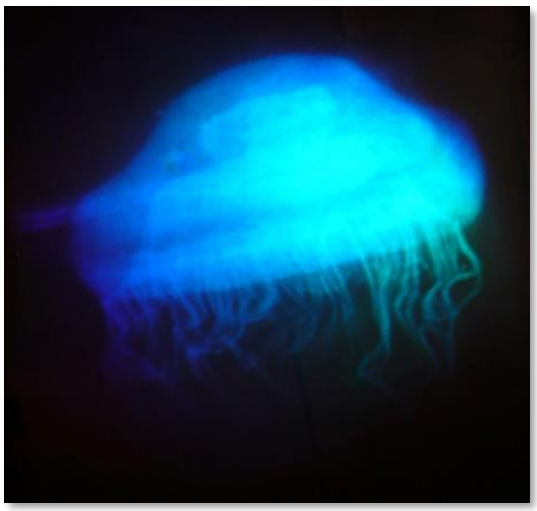
> a bodily connection to the scene is used to forge an affective link between the holographic image and the viewer. (2011, p.26).

For example, in: *Jumping Jellies* (2009), shown below in figures 22 and 23, Mrongovius displayed five analogue holographic jellyfish which were animated vertically by a spectator jumping up and down in front of it on a trampette:

> The viewer and jellyfish elongate to propel themselves upward and then expand as they drop down. The viewer feels their own squishy parts expanding and contracting, a sense that is heightened by seeing the animated jelly form. (Mrongovius, 2009).

In Mrongovius's dissertation, she writes that she wanted viewers of her artwork to become aware of themselves physically by introducing a feeling of discomfort when they saw her work. The holograms act as a tool to manipulate the audience to engage with physical space. Mrongovius brings the audience's attention to their physicality when activating stereograms in awkward physical spaces. The viewer's movement is activated

by the holographic image. Mrongovius describes her work as ‘enticing and structuring movement’ and encoding; ‘a movement through space’. She further refers to the ‘dance of holography’ (2011, p.92). Mrongovius focuses on encouraging the viewer to consider their own embodied gaze.



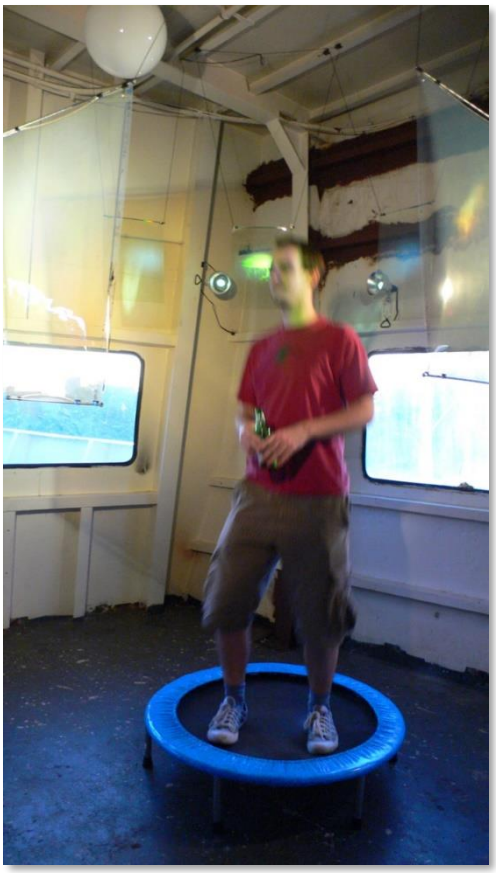


Figure 22 & 23. *Jumping Jellies (I'm going to make you jump)*, installation with transmission hologram and trampet, Martina Mrongovius, 2009.

2.3.2 Emotional affect

In *Art in Holography 2*, artist Jean Francois Moreau links time, space, intimacy and emotion:

> Working on captive time implies new narrative techniques…A new way to discover emotion. (Moreau, 1999).

The second element to the concept of the affective holographic image is the communication of emotion through movement and the images used; artists working with animated holography communicate many different emotions for example, surprise, humour (Boyd, 2017), discomfort (Richardson, 2009; Azevedo, 2011) and nostalgia

(Randazzo, 2004). The effect of an artwork includes two different aspects: firstly, the viewer's physical involvement with the artwork, and secondly, their emotional response to that engagement. The lenticular and holographic image can guide the physical movements of the viewer, and the artist can communicate emotion through the medium and the images portrayed. The work of four different artists (Azevedo, 2011; Mrongovius, 2009; Ohlmann, 2007; and Desbiens, 2009) are presented below. All have used the affective aspect of animated holography to physically manipulate their audience as a result of the interactive nature of holography. Moreover, there is the conceptual space in which holography can appear to store time. My own research offers a new concept of this last aspect of holographic space and this is described more fully in Chapters Five and Six; in the section below, however, the different types of application of space by artists working with three-dimensional imaging are discussed in more detail.

Surprise

The audience's response to the artwork is reliant on their experience with seeing lenticular and holographic images for the first time, and can be predictable. There is a 'wow!' factor for the audience member who sees their first hologram, and engagement with the work can be superficial, what one professional artist during evaluation of my artworks described as 'getting the trick' (Artist A, 2015).

Humour

In *Elvis, Dolly and Molly* (Boyd, 2017), shown below in Figure 24, Patrick Boyd illustrates Elvis impersonators and a child eating an ice lolly. Boyd often uses the comic effect of temporal incoherence to add a further aspect of humour to his artwork.

Figure 24. *Elvis, Dolly and Molly*, animated stereogram, 10" x 8", Patrick Boyd, 2017.

In *Memory II* (1999), shown below in figure 25, Ikuo Nakamura depicts a computer-generated model in the centre of the screen, surrounded by angled screens depicting distressing newsreel footage. In one of the screens, a man is shot as the viewer moves from the left to the right of the screen. The movement of the viewer from right-to-left reverses the scene and the man appears to return to life. In viewing the hologram, the viewer appears to control the devastation shown in the animated holograms, in effect turning back time. However, the viewer cannot help but repeat the movement to watch the film and activate the devastation and is helpless to prevent the disaster.

Unlike Nakamura's work, my own uses different layers to depict different time periods. Within holographic space. Nakamura's use was not structured.

Figure 25. *Memory II*, white light transmission holographic stereogram, 19cm x 23cm, Ikuo Nakamura, 1999.

Nostalgia

In 1993, Jeff Robb produced *Great Aunt*, shown below in figure 26, an analogue multiplex reflection stereogram of an elderly woman drinking tea. The woman in the animated portrait drinks tea when viewed from right to left, or left to right. The image is rich with nostalgia. As the viewer moves from side to side in front of the image, the hologram animates and the woman lifts her cup to drink her tea. The artwork is based on repetition of the movement of both the subject and the viewer. The repetition engenders the piece with an atmosphere of timelessness. The viewer becomes part of the relationship between

the artist and his relative, because the movement is animated by the viewer. The animated artwork provides a connection between the time period in the image with the present time of the viewer activating it.

This is a perfect example of temporal coherence, or symmetrical time (Moreau, 1996). The narrative can be read in both directions;

> The viewer no longer perceives the different points of view, but different moments in time... It can thus be read in both directions without any logical impediment…the meaning remains intact whatever the direction' (ibid.).

The side-to-side rocking motion the viewer makes to activate the animation in a holographic image emphasises loss and nostalgia. Both viewer and artist are re-accessing a memory, and replaying it time after time with the movement of the artwork.

Figure 26. *Great Aunt*, animated reflection stereogram, 20.3cm x 25.4cm, Jeffrey Robb, 1993.

Miggs Borough's portrait over time; *The Journey* (2010) illustrated in figures 27 and 28 below, depicts his mother at ages 17 and 97 years. The portrait ages as the viewer moves from left to right.

The artist Matthew Andrews produces complex lenticular collages from people's family portraits as a commercial artist, as shown below in figure 29, but neither Boroughs nor Andrews uses the image plane to depict the present time, utilizing the Z axis of holographic space to represent chronological narrative as has been done in this study.

Figure 27 & 28. *The Journey*, detail, animated lenticular portrait, 56cm x 56cm, Miggs Boroughs, 2010.

Figure 29. Story Portrait marketing image, Mathew Andrews, n.d.

Bashir Makhoul has used lenticular imaging in a series of works showing Palestinians and Israelis occupying the same space in different time periods in history, using overlapping images within the lenticular as a metaphor of the conflict (Beck, 2012). One of which, *Return in Conflict* (2006), is shown overleaf in figure 30. This innovative application of the media explores aspects of spatial imaging, but the artist does not use the Z axis of space within the artwork to depict the different times, but rather overlapped the images of the different time periods in the same space.

Figure 30. *Return in Conflict*, animated lenticular, (size unknown), Bashir Makhoul, 2006.

2.4 A New Space: Digital Animated Holography

The new medium of digital animated holography, developed by Zebra Imaging in 1996 (LAW, 2008), enables the artist to work with full-colour animated reflection holography. This new technology has its own aesthetic; a new colour palette has been made available to artists who still have the benefits of working with 4D images. The new colour has theatrical impact. The work of Dietmar Olmann (2007), Isabel Azevedo Jacques Desbien (2006), and Martin Richardson (2009) is described below.

Whereas Mrongovius's work described above encourages the spectator to make themselves physically aware of looking, Ohlmann Azevedo's Desbien and Richardson's work draws their viewer's attention to an interactive show, even the work of Desbien depicts an act of unrolling a scroll for a viewer.

Ohlmann's *Glam-O-Rama-Girly-show* (2007), and Azevedo's *Between Memories* (2017), digital animated holograms, depict performances, activated by the movement of the viewer. Both Ohlmann and Azevedo collaborated with professional performers to

choreograph the work. The performance of the artwork is reliant on the movement of the viewer, whose swaying in front of the hologram contributes to the theatrical show playing out in the artwork. Glam-o-Rama-Girl-Show, can be seen below in Figure 31, and Between Memories appears in Figure 32.

Figure 31. Glam-o-Rama-Girl-Show, digital animated stereogram, 18cm x 24cm, Dietmar Olmann, 2007.

Figure 32. *Between Memories*, digital animated holograms, (size unknown), Isabel Azevedo and Elizabeth Sandford Richardson, 2013.

Jacques Desbiens's work illustrates multiple points of view in what he calls a nomadic perspective. One has to walk to unravel his Chinese scroll, *The Broken Window* (2006). Desbiens encourages the viewer to become aware of the differences in representational

systems between the monoscopic perspectival nature of painting and the polyscopic perspective of digital holography (2009) by making them walk. Desbiens draws attention to the surface of the holographic image by depicting broken glass on the surface of the plate, and having a tree-branch protruding through it into the viewer's space, as shown in figure 33 below.

Figure 33. Three views from Broken Window, digital animated hologram, 140cm x 47cm, Jacques Desbiens, 2006.

The digital animated hologram enables the artist to sculpt both in time and space (Tarkovsky, 1986). Martin Richardson's *Atomic Love* (2009), shown below in figure 34 overleaf, uses the device of a mirror within the hologram to connect the times depicted in the hologram (the model's time, and the film's time) to the present-day time of the viewer, ensuring the historical content is linked to the moment of viewing.[11] Using full-colour digital animated holography, Richardson explores temporal incoherence as one aspect of *Atomic Love*. The hologram depicts a woman looking into a mirror with her back to the viewer. In front of her, in the background of the hologram, an atomic bomb is exploding. The holographic artwork is inspired by Alain Resnais' *Hiroshima Mon Amore* (1959), a film which explores themes of memory and oblivion and uses non-linear narration.

[11] The metapicture, then, is also a figure that helps to explain the often-observed uncanniness of images, their ghostliness or spectrality, their tendency to look back at the beholder, or seemingly to respond to the presence of the beholder, to "want something" from the beholder (Mitchell, 2006). http://www.visual-studies.com/interviews/mitchell.html.

Activating the image in the hologram by moving left-to-right and right-to-left in front of it rewinds the film footage in the image of the bomb exploding. The viewer prevents and causes the bomb to explode over and over again.

Figure 34. *Atomic Love*, digital animated hologram, 30 x 40cm, Martin Richardson, 2009.

Figure 35. *Psychedelic Amy*, digital hologram, 72cm x 90cm, Martin Richardson, 2009.

Figure 36. *Cowgirl*, digital hologram, 50cm x 60cm Isabel Azevedo, 2009.

Richardson (2009) and Azevedo (2009) both use animated holography to invade the viewer's space and cause discomfort for the viewer. They use the close cropping and editing techniques of film-makers to fill the frame of the holographic image with their portraits and to get 'too close' to the subject of the hologram, creating emotional impact. According to Bernard Dick, a 'close-up provides a link to psychological space' (Dick, 1999, p.81). The slight projection of the image results in an invasion of the viewer's personal space. In his doctoral thesis, Richardson notes that holographic portraiture invades the proprioceptive boundaries of the viewer (1988); the result, according to art historian Sarah Maline, is a feeling of discomfort that you can move too close to someone and they can't get away (Maline, 1993). Both Richardson's *Psychedelic Amy* (2009) shown in figure 35 above, and Azevedo's *Cowgirl* (2009) in figure 36, are digital holographic portraits of women whose faces are literally larger-than-life, which seems to empower the subjects. The viewer's face is smaller than the portrait, which renders the viewer child-like in comparison as they move in front of the large holographic faces to animate them.

2.6 Authenticity

The authenticity of an image is a combination of three different aspects: (a) the technology itself, or the manner in which the photographic, or holographic image is captured; (b) the subject matter in the image; and (c) its method of display.

When an analogue camera records an image, the amplitude, or brightness, of light and the wavelength, or colour, is captured in a photograph in light sensitive chemistry. Light reflects off a subject into the camera lens and is focused and recorded onto a silver halide material during the photographic exposure. When an analogue holographic plate records an image during an exposure, the amplitude, wavelength and phase of a light wave is recorded. The phase of the light wave and interference pattern created throughout the holographic plate is what records the depth of the holographic image. It can be argued that holography produces a more authentic copy than the photograph. With the addition

of the requirement for the viewer to move to view a digital animated hologram, the viewing emphasises the 'here and now', and the viewer has an affective experience.

Different types of technology record and represent time differently as a result of their different qualities. There are three different aspects to the development of the aesthetic vocabulary of holography and lenticular imaging which are most pertinent to this study: the temporal; the spatial; and the role of the audience in creating and perceiving the artwork. This section briefly explores the development of the art media. The holographic work of art, despite capturing time and space, is not a copy, but its own original.

2.7 Summary

The research question asks, 'Can temporal and spatial coherence be achieved in holography and lenticular imaging to create a new artform, providing new impactful, affective experiences for an audience?' The terms 'temporal' and 'spatial coherence' in this context relate to animated three-dimensional images whose narrative is chronologically ordered within holographic, or lenticular, virtual space.

As soon as artists were able to work with animated holography, they explored concepts of manipulating time, extending time and sculpting in time. Time can be extended in two ways: through the repetitive action of viewing the hologram, and the inclusion of the viewer within the system of the work of art. Moving from side to side in front of a horizontally animated image replays the image over and over again. The 4-D image can be coherent or symmetrical (Moreau, 1996), or incoherent (Desbiens, 2009). These terms refer to an animated image which does, or does not, make narrative sense when an image is animated by the movement of the viewer and 'played' both forwards and backwards. While some artists explore symmetrical time within holograms, such as Jeff Robb (1993), Dietmar Ohlmann (2007) and Isabel Azevedo (2011), others explore the lack of symmetry – they probe the meaning of animations which run backward and rewind (Randazzo, 1991; Desbien, 2009).

My own research layers multiple animated images and uses virtual holographic and lenticular space to represent a chronological narrative, adding an extra dimension to the

issue of temporal coherence, thus considering temporal *and* spatial coherence. I propose that an animated image is temporarily and spatially coherent if the virtual Z axis in the 3-D image, is used to represent time. In other words, further back in holographic and lenticular virtual space and further away from the viewer represents further back in chronological time. This use of holographic space, which incorporates the position of the viewer of the artwork within the conceptual frame of holographic space and time, leads the author to consider the role of the viewer in the artwork as integral to the artwork, as will be discussed next.

None of the artists mentioned above, however, have as yet used the Z axis inside and outside the hologram plane – or lenticular plane – to represent chronological time, and it is the author's intention to focus on this aspect of my research. The following chapter outlines the approach to the research that has been undertaken.

3 METHODOLOGY

The research questions addressed in this study are creative and conceptual, requiring a practice-based methodology to answer them. The purpose of the study was to create a new aspect of the lenticular and holographic artform using the Z axis of lenticular and holographic space to present a chronologically ordered narrative. The artworks containing the new application of the Z axis were to provide an audience with a new experience with an authentic, affective impact. This chapter describes the practice-based research methodology undertaken in the study and includes the following: (1) a definition of the practice-based methodology undertaken; (2) a rationale for, and description of, the methodology and methods chosen; (3) an overview of the research design, with a chronological summary of the research process; (4) an overview of the technical methods of production of artworks; (5) an outline of the methods used to evaluate audience experience of the works; (6) a description of audience involved in the research process; (7) ethical considerations of the study; and (8) the limitations of the study. The chapter concludes with a brief summary.

3.1 A practice-based methodology: a definition

This study relies on a practice-based methodology as described by Linda Candy:

> Whilst the significance and context of the claims are described in words, a full understanding can only be obtained with direct reference to the outcomes' (Candy, 2006, p.3).

The research does not intend to lead to new understandings about practice.[12] The contribution to knowledge for this research, therefore, is to be found both in the artefacts

[12] Candy differentiates practice-based and practice-led thusly:

1. If a creative artefact is the basis of the contribution to knowledge, the research is practice-based.
2. If the research leads primarily to new understandings about practice, it is practice-led' (2006).

The terms 'practice-led research' (Smith and Dean, 2009) and/or 'practice-as research' (Nelson, 2013) have also been used to describe the artefacts created, along with the accompanying discourse, as containing new knowledge.

produced and the dissertation which communicates the knowledge. Lenticulars, analogue and digital holographic artworks were the creative outcomes of this practice-based study, and they are fully described in Chapter Five, the results section of this dissertation. These artworks, along with their analysis and this dissertation, form the study's contribution to knowledge.

3.2 A practice-based methodology: a rationale

The methodology used in this study was typical of other practice-based researchers working with interactive media (Dawson, 1999; Costello, 2009; Mrongovius, 2011; Tine Bech, 2014), all of whom reported undergoing an iterative process of creating, observing, and reflective practice. Mrongovius describes a process of experimentation; through making and installing/exhibiting holograms, reflecting upon the affects and outcomes, and feeding this back into subsequent experiments' (2011, p.10), a process resulting from the experience of a professional's practice as first described by David Schön (1991).

Exhibiting artwork as part of the research process enabled Bech, Mrongovius and I to observe viewers engaging with the artwork in a number of different environments, an important aspect of the research process. During the course of my studies, I took part in four exhibitions, each one an opportunity to develop concepts and solve practical questions. Unlike the process undertaken by Dawson, Bech and Mrongovius, though, audience members were not only observed interacting with the works, but also surveyed to determine the affective impact of the artwork. This approach gained more objective results than just my own observations of my own work, or of others interacting with it, to determine whether the exhibition aims had been met and the research question had been answered. This approach, which used both arts practice and evaluation, has been described as 'common and well-established within practice-based research methodologies' (Gray, 2004 and Nelson, 2013); however, it is novel within the context of holographic art practice research.

3.2.1 Why use lenticular and holographic media?

This study relies on lenticular and analogue and digital holographic media as a result both of my extensive experience working with holography, and the opportunity to expand its aesthetic vocabulary.

The research question developed as a result of my working with holography as an artist for over thirty years. This development is described further in the next chapter, which describes the foundation to my research.

The medium of holography is very different to other forms of artistic imaging, such as painting or photography, in that holography represents three-dimensional space via a two-dimensional plane and does not use perspectival systems to create an illusion of space (Dawson, 2011). However, both lenticular and holographic media contain the ability to not only depict depth within their virtual space, but also display images in front of the image plane and straddling the plane of the image[13]. Jens Schröter (2014) describes the representational system as 'transplane'; this aspect of lenticular and holographic media provides an opportunity for research to question whether the Z axis within the volume of illusory space can represent chronologically ordered imagery.

It could be argued that there are other technologies which can produce transplane images: Virtual Reality (VR), anaglyphs, stereo photographs or 3-D film (which relies on different types of polarisation to create three-dimensional images). However, lenticular and holographic media do not rely on using intermediary equipment such as stereo viewers, headsets or glasses to provide illusory depth. The very act of looking is impacted or influenced by the use of viewing equipment and these mitigating factors are uncomfortable and even painful for viewers (McIntire et al, 2014). Auto stereoscopic methods for producing three- and four-dimensional images were chosen instead for this study.[14]

[13] This aspect of holographic imaging was described by artist Andrew Pepper in a generalised graphic definition in *Leonardo* (1989, p. 295), illustrated in Figure 3 of this dissertation.

[14] While stereo-pairs of photographic imagery can be viewed without glasses they cannot be animated and are therefore unsuitable for this 4-D study. Also, 12% people have impaired stereoacuity and are unable to see 3-D images using stereo-pairs due to either medical or perceptual issues (Wikipedia contributors, 2018), impacting the ability of the audience to engage with these artworks and limiting audience numbers.

3.3 An overview of the research design

This section provides an overview of the research design and is modelled on that of Brigid Costello (2009). The overview consists of the following elements: (a) a chronological summary of the research process; (b) an introduction to audience involvement; (c) a description of the methods of evaluation of the artworks produced as part of the study; and (d) the ethical implications of the study. The research design undertaken during this project is divided into three sequential phases and each phase is briefly summarised in Table 3 below, describing a chronological summary of the process.

3.3.1 Phase 1

The first phase of the research involved the creation of a body of eight lenticular artworks entitled *Picoseconds 1, Picoseconds 2, Picoseconds 3, Nanoseconds 1, Nanoseconds 2, Days, Aeon 1* and *Aeon 2.* These lenticulars were presented to the general public at the Royal Society's Summer Science Exhibition, London, 2012, in an exhibit entitled *In Time,* and illustrated in Chapter Five.

The works were first evaluated by the author as part of the iterative process of visualising, testing, making and experiencing the works. Evaluation of audience experience was then made by observation only at this initial exhibition. To gain a better understanding of the audience's experience, the artworks were re-exhibited to a smaller audience both at the University of Southampton and to a small focus group of professional artists in Phase 2. The research methods and the research question were refined as a result of the first phase, and a pilot evaluation method was chosen for the next phase of work.

3.3.2 Phase 2

The second phase of the research involved the development of body of analogue holographic artworks, which were exhibited as part of an installation in *The Virtual Artist* solo exhibition at the University of Southampton. Ten analogue holograms were created in 2014; they were all different sizes and exhibited with methods heavily influenced by the methods of conservation and display used in the environment in which they were exhibited. The pieces were as follows and are described in detail in Chapter Five: *Miner's*

Lamp: Great-Great-Grandfather, The New Clock: Self-Portrait, Dinner Plate: Mother, Boxer Sketch: Grandmother, Silver Shoes: Sister, The Compass: Great Grandfather, The Camera: Father, The Portrait: Great-Great Grandmother, The Wedding Photo: Grandfather, The Necklace: Aunt. These artworks were exhibited with family heirlooms, which were selected objects relevant to the content of each hologram. Illustrations of some of the objects are shown below in figures 37-37.

The second phase included two different methods of gathering audience feedback: a survey of audience experience via questionnaire, and a focus group of professional artists. The results were used to refine the research question and develop previous ideas and strategies for creating artwork (Costello, 2014).

Figure 37. 1st World War Compass, Collection of the artist

Figure 38. The artist's shoes, preserved in silver, collection of the artist

Figure 39. Miner's Lamp, collection of the artist

3.3.3 Phase 3

In the third and final phase, a digital holographic artwork entitled *Passing Time, Distant Memory* was created and exhibited to the general public at the City Museum in Aveiro Portugal, during ISDH2018 and a paper of the same name about the work of art presented at the symposium (JOHN, 2018). The digital hologram is described and illustrated in Chapter Five of this dissertation. The audience experience of the digital hologram and two works produced in Phase 2 of the research were evaluated by an international group of experts attending the symposium. This final phase tested the insights that were developed in Phases 1 and 2 and resulted in the project's final conclusions.

3.3.4 Summary

During these three phases of the study, two different approaches were taken. The first consisted of the visualisation and production of artworks and was followed by reflexive analysis; further practice and analysis; exhibition of artefacts; documentation; and the interpretive analysis of artworks. The second approach consisted of methods relating to the evaluation of the audience experience of the artworks: observation of audience interaction; survey; critique group; and analysis. Sections 3.4-3.6 describe each of these approaches, the methods used and their purpose within the research.

3.3.5 A Chronological Summary of the Research Process

Table 3 Chronological Summary of the Research Process

	Action	Method/s	Outcomes
Phase 1	Creation of a body of artworks: *Picoseconds 1* *Picoseconds 2* *Picoseconds 3* *Nanoseconds 1* *Nanoseconds 2* *Days* *Aeon 1* *Aeon 2*	Practice, reflective evaluation and refinement	Development of research question
	Public Exhibition of above works	Informal observation of audience Documentation	Development of evaluation methods
Phase 2	Analysis of existing artworks	Interpretive analysis	Generation of ideas and strategies for artwork creation Refinement of evaluation methods
	Creation of artworks: *The Compass: Great Grandfather* *Miner's Lamp: Great-Great-Grandfather* *The New Clock: Self-Portrait* *Dinner Plate: Mother* *Boxer Sketch: Grandmother* *Silver Shoes: Sister* *The Camera: Father* *The Portrait: Great-Great Grandmother* *The Wedding Photo: Grandfather* *The Necklace: Aunt*	Practice, reflective evaluation and refinement	
	Exhibition	Documentation Theoretical synthesis	
	Evaluation	Documentation Focus group interview Survey	
Phase 3	Analysis of existing artworks. *Passing Time, Distant Memory*	Practice, reflective evaluation and documentation Focus Group, Survey, coding, analysis	
	Exhibition	Focus Group Evaluation Theoretical synthesis	Final Conclusion reached

3.4 Methods of production of the artworks

The methods described above include visualisation and production of artworks. As the processes are not in themselves novel, a full description of the methods of production for the lenticulars, analogue, and digital holograms can be found in Appendix I: Methods of production.

3.4.1 Collaborative Practice

Several aspects of making the artwork for this study necessitated an element of collaboration with skilled professionals. I have at times produced my artwork with assistance from professional technicians and makers. This approach is a common feature of contemporary art practice in general. My working conditions have been described in the essay *New Media* by researcher Simon Biggs, interviewing new media artist and researcher Johnannes Birringer: 'My practice is made outside the University. I have to work on my own, with my own materials or find and pay other people to work for me. The theoretical part of my research gains more advantage from my academic position' (Biggs, 2009, p.73). Biggs explains that the technical complexity of interactive artworks requires different types of expertise and it is unusual to find one person with all these skills. For this project, these collaborations were in the skills areas of photography, film-making, large format lenticular printing and digital holography. The Virtual Artist exhibitions were documented by an independent professional photographer; Rob Luckins, and University of Southampton film-maker; Stephan Caspar, for the purposes of marketing future exhibitions. The author also sought the assistance of two commercial producers; Jon Mitton created the large format lenticulars (Mitton 3D) and digital animated holograms were produced by GEOLA Digital UAB, both of whom were commissioned by the author to produce final works after detailed and thorough preparatory work and materials testing for the pieces were performed by the author at De Montfort University, the University of Southampton and at the author's own home in Southampton.

Scientific data formed the basis of work produced in Phase 1 and the selection of suitable visual data required a good deal of dialogue and negotiation with the participating scientists, Drs Belyaev, Fanghor, Jones, Kammann, Nesbitt, Scaife, and Slavcheva, and

Professors Bird and Franchin at the University of Southampton. The discussions resulted in a selection of scientific data from astronomers, laser scientists, specialists in magnetism and nanotechnology. Diachronic images were selected that could address issues of temporal and spatial coherence in relation to the research question. The selection and production process also included testing different data sets to ensure their suitability for lenticular imaging, evaluating results and adapting processes accordingly.

3.5 Study participants

There were two main groups of study participants. Firstly, the family members who were featured in the artwork, and secondly, the audience for the artwork. The type of audience selected to take part in the evaluation of the artworks evolved as a result of the research process; it was evident from evaluating audience experience in Phase 2 that different aspects of the research question were relevant to difference audiences. The audiences included the general public, professional artists, and other artists working with holography. An evaluation of the general public's and a group of professional artists' experience of the work is described fully in Chapter Five of this study. The results of the study are mostly likely to have an impact on artists using lenticular imaging and holography as the results expand the artistic vocabulary of the medium. However, the general public have benefitted from the research process by seeing the study outputs during exhibition attendance and even by participating in the research.[15]

3.5.1 Why evaluate audience experience?

> 'For the artist evaluation supports different aspects of their creation and research and is inter-disciplinary and experimental' (Alarcon-Diaz, 2014, p.187).

The audience experience was evaluated as part of the research process for four reasons: (a) the viewer was an integral part of the artwork; (b) the study's research question asks whether the artworks gave the audience a new experience and postulates that the artwork had an authentic, affective impact on the viewer; (c) the reflective process involved in a practice-based methodology involves discussion with others and gaining other

[15] Holography experts who took part in the evaluation in Phase 3 declared how much they had enjoyed the process, and I have been invited to write a journal article about the critique.

perspectives (Candy, 2004); (iv) the current climate in higher education encourages audience involvement with research. Aspects of the above are discussed in greater detail below.

3.5.2 Audience interaction

Lenticular imaging, analogue and digital holography are interactive time-based media in which the audience member creates the temporal and spatial aspects of the 4-D media by moving in front of it to create an animation. As such, the audience member was necessarily a participant in the research process (Alarcón-Diaz, 2014). The study's research question asked, 'can a new element to the lenticular and holographic artform be created which provides an audience with a new experience with an authentic, affective impact?' This question necessitated the evaluation of audience experience, rather than just observation. Artist and academic Ernest Edmonds argues that;

> 'It is impossible to directly observe the inner feelings of the audience…being able to explore the "interaction space" involves some form of evaluation with audience cooperation' (Edmonds, 2011, p.2).

3.6 Evaluation Methods

A summary of the different methods of analysis and evaluation are shown below in Table 4.

Table 4 Evaluation methods employed in study.

Description of Project	Evaluation Method	Outcome
Project 1: *In Time* Exhibited at the Royal Society Summer Science Exhibition, London.	Artist's own analysis and evaluation of artworks Audience observation only	Analysis Design of formative evaluation method
Project 2: *Virtual Artist* Solo Exhibition, Special Collections Gallery. University of Southampton.	Artist's own analysis and evaluation Audience observation Questionnaire Professional Artists Critique Session	Responses analysed Discussion transcribed, coded and analysed.
Project 3: *Time and Space (Group)* Exhibition, City Museum, Aveiro, Portugal.	Artist's own analysis and evaluation of works Audience observation Professional art/holographers critique session	Discussion transcribed, coded and analysed

The methods of evaluating and analysing audience feedback are shown above in the summary table of evaluation methods, Table 4 above. This section describes the methods used to make a formative and summative evaluation of audience experience of the artwork produced in the study. These methods included the following: (a) the artist's own observations of the artwork; (b) the artist's observation of audiences interacting with the work; (c) gathering and analysing written feedback from audiences obtained via on-line questionnaires; and (d) feedback from critique sessions with professional artists and artists working with holography in Phases 2 and 3. The methods of evaluation had to be adapted to suit different exhibition environments as the study progressed; Phase 1 was evaluated through the artist's own observations and reflections only, whereas Phase 2 involved a triangulation method consisting of observation and reflection, feedback from questionnaires, and a critique session with professional artists, using methods informed by social science. The last phase included audience observation and a critique session with professional artists working with holography, which again was evaluated using methods informed by social science. The limitations of the study are outlined in section 3.7.

3.6.1 Artists observations

Two different aspects of observation were relevant to this study: the artist's own observations of the artworks, and the artist's observations of others reviewing the artwork. Previous methods of lenticular and holographic artwork evaluation have relied solely on artists' own observations of their artwork as and of others reviewing the artwork. This is an important element of the research and Chapter Five includes the author's own observations of the artworks produced in the study. The process is discussed by artist David Pizzanelli, as follows:

> Observations of the effects of temporal and stereoscopic parallax were made directly by the author, and the proof of these effects is provided in the form of multiplex holograms for the reader's scrutiny, rather than by conducting clinical trials with test subjects. (Pizzanelli, 1994, p.2).

While observation of audience interaction is an important aspect of a practice-based methodology, the method is problematic as a research tool; it is difficult to be objective.

In defence of this method, artist and researcher Tine Bech argues, 'the counterargument is also acknowledged that researchers cannot claim to be isolated from culture and society, we are "in" the world, the world is not "out" there…it is only by recognising this "situated subjectivity" that it can instead serve as a resource for deeper understanding' (Bech, 2014, p.69). Bech describes her observations as non-participatory and unstructured, mainly consisting of 'hovering around' near the artwork. I made notes and took photographs to document the process during exhibitions. However, surveying audiences' responses contributed rich data to the research process.

3.6.2 Phase 2

A questionnaire was emailed to exhibition attendees three months after the end of the *Virtual Artist* exhibition via SurveyMonkey to obtain feedback about the audience's experience of the exhibition. Email addresses were gathered both from the original preview invite list and from those that left their contact details in the comments book after they had agreed they could be contacted.[16] Questions asked were to gather both quantitative and qualitative data and were designed to ascertain the audience's general interests, whether in science or in art (or both) and their previous experience of attending both art, and art and technology exhibitions. The audience were also asked for their thoughts on the exhibition itself. The questions and summary of audience answers can be found in the Appendix of this paper.

3.6.3 The silent researcher critique

A 'Questions' feedback session with professional artists was used to evaluate Phases 2 and 3 of the study. This method is described as the 'silent student' critique when used in educational settings (Elkins, 2014) and will be described as the 'silent researcher' critique for the purposes of this study. The group of artists consisted of three participants and can also be described as a 'mini-focus group'. Social scientist Anthony Onwuegbuzie describes this limited number of participants as acceptable when participants have specialised knowledge (2009).

[16] Email addresses were gathered before the EU GDPR law came into force, consequently the database has been erased.

The silent critique method was introduced to the researcher during the second phase of the research study. The method was used by the facilitator of an informal network for professional artists based in Hampshire[17]. The silent critique differs from a focus group in two ways. Firstly, the researcher does not speak during the session, so is unable to guide participants to answer their research questions. Secondly, participants are encouraged to address the researcher only, rather than each other (however, in practice this is not always the case).

Silence is recognised to be a useful interview tool when used by the facilitator, enabling the participant to complete their response (Lerpiniere, 2015). The benefits to the use of silence was evident during the critique session too; members were given the opportunity to finish their thoughts when the researcher did not answer back, and when posed as a question, participant comments were carefully considered and formed. The group was held on 13 October 2014 and lasted for one-and-a-quarter hours. An audio recording was made by the critique session organiser, with the participants' permission, then the discussion was transcribed verbatim by the author. This process resulted in a wealth of qualitative data, so was repeated again in Phase 3 of the research, using a group of experts in art and holography.

3.6.4 Phase 3

The method of evaluation applied to Phase 3 of the research was determined by the limited availability of the audience for the artwork. The audience consisted of international experts in art and holography who were gathered at the four-day International Symposium on Display Holography 2018, Aveiro, Portugal where the artwork produced in Phase 3 was exhibited. The symposium had a packed schedule and time off for the participants was very limited. The symposium is triennial, with many participants only seeing one another every three years and, as such, the networking time was very precious for participants. I arranged for a specific audience to gather for one hour during a symposium lunch time to evaluate the artwork.

[17] The facilitator of the group is not credited here to enable them to remain an anonymous contributor to the research process.

The evaluation methods typically used to evaluate interactive art; log-data, video footages, interviews, and questionnaires, (MORREALE and DE ANGELI, 2007; MORRISON et al, 2006) were considered. A questionnaire was prepared for the purpose of audience evaluation, however due to the scheduling of the symposium, my paper on my research was presented before the evaluation could be undertaken. The scheduling for the evaluation was done in conjunction with the Co-Chair of the symposium Art Committee and the curator of the Aveiro City Museum in Aveiro who had to enable access to viewing the artwork.

I was concerned that seeing my research presentation *before* seeing my artwork may unduly influence participants' answers on the questionnaire. I was also aware that I had a very limited amount of time for access to both the symposium delegates and the exhibited artwork, so the decision was made the decision to use the silent researcher critique method of evaluation in Phase 3, which had proven to be successful when piloted in Phase 2.

The criteria for the selection of participants were those with doctorates; doctoral candidates; long-standing or award-winning artists working with holography; and university or college teachers in art and holography. [18]

Nine Experts in art and holography attending the International Symposium on Display Holography in Aveiro, Portugal, responded to a general invitation to assist with the evaluation of three artworks produced during the study, one of which was displayed on the wall as part of the exhibition Art in Holography: Light, Space & Time at the City Museum in Aveiro. This evaluation of the artworks contributed to the summative evaluation of the study.

Nine experts contributed to the evaluation process. The group consisted of three men and six women, from the USA, Canada, Portugal, UK, Australia, and Taiwan. Two members

[18] A delimitating time frame of five years was decided on by the researcher to ensure adequate experience of holographic art. This time-span was chosen as it correlated to the amount of time taken to complete a Master's degree for the artists who had not necessarily had a formal education.

of the group had English as a second language. A table summarising the experts is shown below in Table 5, however some information is omitted to ensure anonymity for the participants.

Table 5 Phase 3 Silent Researcher Critique List of Participants

Participant code	Participant profile: Level of education/experience
Expert A	Artist working in holography for 30+ years (female)
Expert B	Doctorate (male)
Expert C	MSc. Artist working in holography for 30+ years (female)
Expert D	Doctorate (female)
Expert E	Doctorate (female)
Expert F	Ph.D. Candidate (male)
Expert G	Ph.D. Candidate (female)
Expert H	BA: Art Faculty member (Male)
Expert I	MSc. Artist working in holography for 30+ years

The experts were asked to view and analyse three art works; two from Phase 2 of the project and a third from Phase 3. Two of the artworks were monochromatic mixed media works incorporating analogue holograms, shown in Chapter Five: *Great Grandfather* and *Great Grandmother*. The third was *Passing Time, Distant Memory*, a digital hologram. The first two holograms were handed to the experts to view under overhead lighting in the Aveiro Museum Gallery space; this required the manipulation of the objects to light the embedded holograms at the correct viewing angle. The third hologram was framed and lit as part of the exhibition.

The questioning technique was unfamiliar to participants so at times they found it difficult to phrase their comments as a question in the Phase 3 session (most particularly for one researcher who did not speak English as a first language) and the group did discuss the work with one another, despite being asked to address questions to the researcher only.

The author provided transport to and from the symposium to the City Art Gallery and provided refreshments after the session to recompense participants for their valuable time

taken up by the research, which took them away from important networking opportunities at the international symposium.[19]

The session was filmed and audio-taped. The filming enabled a better understanding of artists' views through observation of their body language and gestures, which became an important part of one participant's method of communication as English was not their first language. Filming and recording were done by fellow researcher Tove Dalenius, from De Montfort University.

3.6.5 Data Analysis

The group critique of the artwork was transcribed as recommended (Elkins, 2004), coded, and themes generated and analysed using a general inductive approach. The purpose of this approach was to make links between the evaluation aims and the results gleaned from raw data (Thomas, 2006). This approach is considered by Thomas most appropriate for project evaluation by researchers unfamiliar with any of the traditional approaches to qualitative analysis (2006). Qualitative data analysis software (NVivo 11, 2017) was used to speed up the coding process and the evaluation objectives provided a focus for the analysis.

3.7 Study limitations

The study design had a number of limitations which included: informal observation methods; audience members not being representative of the general public; drawbacks of using the silent researcher method for feedback; and a lack of validity for the first silent researcher critique group. These aspects are described in further detail below.

3.7.1 Observation limitations

The study would have benefitted from adopting more formal observation methods such as those used by Bech who notes 'the observations serve to record people's physical

interactions and to allow evaluation of the artworks according to my artistic intention and research questions' (2014, p.68). However, Bech did not survey audience members about their experiences and analyse the results to evaluate audience experience, so this study's approach was considered comprehensive enough by the author. Future studies by this author, though, will use more formal record-keeping of audience observations.

3.7.2 The participant group

The audience participants were not representative of the general public due to their age range and their relationship to the author. The age range and demographic of the attendees who responded to the participant survey was impacted by the exhibition venue. 22% of the attendees were between 18 and 30 years old, and were observed to be university students, while over 27% of attendees were over 60 years old, with no-one under 18 years attending. These percentages are not typical of the demographic usually seen at exhibitions (Black, 2006).[20] The exhibit was located in the University of Southampton library, which had limited opening hours during the day and was closed at the weekends. This schedule prevented those working from attending the exhibition. However, great efforts were made to market the exhibition to ensure the largest possible audience numbers attended. The exhibit was advertised to the general public during a radio interview between the author and *BBC Radio Solent* presenter Katy Martin. The show had approximately 25,000 listeners. The exhibition was also advertised in the *Daily Echo*, so had good local press coverage. Within the context of the venue, the number of attendees was considered very successful. Another aspect limiting the validity of the survey was that over 78% of the attendees described themselves as friends, family or colleagues wanting to be supportive by attending the exhibition, so the group was not representative of the general public. However, the next exhibition space used in Phase 3, in a public museum, allowed for a wider demographic and larger audience numbers.

[20]In *Engaging Museums for Visitor Involvement*, Graham Black describes the typical audience demographic for museum visitors. 'Davis suggests most age ranges are represented relatively equally in UK museum audiences, but with smaller percentages for 16- to 24-year-olds and those over 55 years old. The more recent MORI survey suggests increasing problems in attracting the adult audience under 35 years' (Black, 2005).

3.7.3 The silent researcher method

A limitation of the 'Questions' or 'silent researcher critique' method used was that the researcher is unable to steer the discussion if evaluation topics relevant to the aims and objectives of the project are not being discussed, as is possible with a focus group. However, there are many benefits association with the method, as has been discussed previously. Because the researcher remains silent, the speaker is allowed to complete thoughts and sentences; and the process ensures that the viewer is in control of describing their experience, even if it doesn't relate to the evaluation aims.

3.7.4 Reliability of data interpretation:

David Thomas points out that the interpretation of qualitative data is influenced by the evaluators:

> Inevitably, the findings are shaped by the assumptions and experiences of the evaluators conducting the study and carrying out the data analysis. (2006, p. 240).

The process and methods of evaluation developed during the study; validity could not be established for the Phase 2 analysis as codes were developed by a single researcher, however, the problem was mitigated for in Phase 3. Another researcher from the author's research group Tove Dalenius, was trained in rudimentary social science methods of coding, and she checked both the transcript and the coding. Dalenius wrote a statement to confirm the authenticity of the process:

> 'The transcript correctly describes the discussion and individual contributions. and the coding process undergone by the author' (Dalenius, 2018).

It would have been preferable to use a social scientist to check the coding as those researchers would be more familiar with coding; however, the content of the discussion would have been very difficult for non-specialists to understand.

3.8 Ethics

The study received ethical approval from the Art, Design and Humanities Faculty Ethics committee of De Montfort University on the 29 March 2012. The study used archived data in which individuals are identifiable. Permission was obtained from family members to use their photographs, film footage and precious objects in the artwork and to retain the photographs indefinitely.

Areas of concern regarding the ethics of the study included the gathering of information from or/and about human beings through on-line questionnaires, observation of human behaviour and focus group (critique) sessions.

Respondents were informed of the following information at the beginning of the critique sessions:

i. that recording equipment would be used and that the discussions were to be transcribed.
ii. Respondents' anonymity was strictly preserved.
iii. Respondents were told to whom the information they gave would be supplied and the purpose for which it would be used, and also that
iv. Respondents' co-operation in a research project was entirely voluntary at all stages.

Respondents were informed that film and audio recording of them was to be destroyed after five years. Participants signed forms to agree to take part in the research process. They were made aware that they could withdraw from the process at any time. All the participants were given my contact details and were made aware of how to see the results of the research process.

3.8 Summary

This chapter has described and defended the practice-based methodology undertaken to answer the study’s research question. The rationale for using the practice-based methodology included the researcher’s lengthy experience of working with lenticular and holographic imaging and the suitability of those transplane media to display chronologically ordered imagery within the Z axis of holographic space. The research

question necessitated an evaluation of audience experience because an audience is integral to producing the animated artworks, and the research question also asks whether the audience is given a new experience with authentic, affective impact in viewing the works. Different audiences were invited to participant to answer different elements of the research question. The aim of the formative evaluation was to explore new ideas, and develop understanding and the works as a result of that process (Alarcón-Diaz, 2014). The aim of the summative evaluation was to determine whether the study's research questions had been answered and a contribution to knowledge confirmed. (Edmonds, 2006). The limitations of the study and ethical concerns of involving participants were addressed. The next chapter describes the foundation work which led to the development of the research question, and is followed in Chapter Five by a description of the results of the study, including both the new artworks created and the evaluation of the work by audiences.

4 FOUNDATION WORK

This brief chapter provides a description of the artwork which acted as a foundation to this study. This foundation includes the work I produced in the 4-D Department while studying for a Bachelor of Arts Combined Honours degree at Exeter University (1987-1990), and the holograms I produced during my Master of Arts degree at the Royal College of Art (1990-1992).

I saw my first hologram, a multi-channelled animated rainbow transmission, on a shopping trip to Covent Garden in 1984. As I walked past a shop window of the *Light Fantastic Gallery* [21], a spectrum of light and movement caught my eye. The hologram, a multi-channel white light transmission hologram, looked like an animated stained-glass window. I thought it was magical. I looked around the exhibition and was so inspired I knew where my career path lay. I worked at the gallery on weekends, took my first course in holography at *Richmond Holographic Studios* in 1984, then another course with Martin Richardson in 1986. I had work experience with *Colour Holographic* in 1987 and joined the Royal Photographic Society's Holography Group. I built my own holography studio in my parent's garage and interviewed Margaret Benyon about her artwork during my Foundation Year course, also in 1987.

I attended Exeter College of Art and Design from 1987-1990 and was situated in the 4-D Department during the last two years of a Combined Honours Bachelor of Arts degree course at the University of Exeter while studying fine art and English literature. My artwork at that time explored the integration of text and visual material through projected images, video, film and text.

4.1 The Royal College of Art (RCA)

Both Margaret Benyon and David Pizzanelli were completing PhDs at the RCA while I undertook my Master of Arts degree in Holography. Benyon's thesis outlined the use of

[21] The Light Fantastic Gallery was located at 48 South Row, The Market, Covent Garden (June 1982). It was the first gallery in the UK promoting holography and the works of holographic artists.

holography as an art medium, and Pizzanelli's topic was *Aspects of Spatial and Temporal Parallax in Multiplex Holograms, a study based on appropriated images*. The research of both artists was inspirational. Pizzanelli's research introduced me to the use of appropriated images, and although his research question focus was on the technical aspects of stereo-imaging in holographic artworks, I was also struck by the emotional impact of his work and atmosphere of nostalgia within the imagery. An example of a work produced during his study is shown below in figure 40.

Figure 40. Hologram from Eadweard Muybridge's *Studies of the Human Figure in Motion*. Multiplex hologram, 20.3cm x 25.4 cm, David Pizzanelli, (n.d. approx.1990-1992).

My own research project involved experimental film editing with multiplex holograms. With a background in video making and installation, I was faced with the new problem of having to limit my animation to 20 frames per hologram, so a strict selection process began of experimentation with editing for multiplex holograms. I produced artworks incorporating time, movement and travel (actual and metaphorical). I filmed shop fronts and newspaper articles while en route to college in the mornings, then edited images to produce multiplex holograms. Two holograms that were produced as part of the project; *Shop* (1992)[22] and *Media Men* (1992), are illustrated below in figures 41 and 42. Both artworks explored issues of consumerism and movement; both the movement of subject matter and the movement of the artist.

[22] *Shop* was purchased by the collector Jonathan Ross in 1992. The work was exhibited in the show Holography Unit at the Glue Factory 14/09/12-5/10/12, but was destroyed by the damp environment in the gallery during the exhibition. The loss of the hologram increased my awareness of conservation issues with holograms.


Figure 41. *Shop*, and Figure 42. *Media Men*, white light transmission multiplex holograms, 10”x 8” Pearl John, 1992

The holograms I had produced made me want to explore temporal issues in holography further.

4.2 An introduction to authenticity

During the period of study at the RCA, my Grandfather died. I made a hologram from a photograph of him and I, shown below in figure 43, but I considered it a failure. The image of my Grandfather was so far behind the image plane that the photograph was out of focus, and the image of me as a child had been lost from the bottom section of the hologram due to uneven illumination and poor positioning of the object beam during exposure. However, the image haunted me; the space between the plate and the image seemed to me to imbue the image with a sense of loss and distance. I was unsure whether the image was impactful just to me because of the personal subject matter.

While at the RCA I was introduced to the work of Rosy Martin. She had lost her partner Joe Spence and was exploring recovery from grief through photography as a result. Martin described how she was haunted by Barthes’ contemplation on the affective dimension of photography in *Camera Lucida: Reflections on Photography*, with the concept of a photograph’s *punctum* or emotional prick (1980, p.27). Martin described how Barthes searched for a likeness that could begin to represent his feelings for and memory of his mother, who had recently died, Barthes concludes:

> This new *punctum*, which is no longer of form but of intensity, is Time, the lacerating emphasis of the *noeme* ('*that-has-been*')" (1980, p.96).

Figure 43. *Grandfather and I*, reflection hologram, 10.2cm x 12.7cm, Pearl John, 1991

In her curatorial essay for Martin's exhibition, *On space, memory and metaphor: the landscape in photographic reprise*, Martha Langford writes:

> Our autobiographical memories also reside in a spatial framework; everyday experience reminds us of that fact. (In MARTIN, 1999)

My research creates a structure to that spatial framework that Langford describes by working with the Z axis in holographic space to create a new affective geometry. The next chapter describes the artworks that have been produced in this study along with evaluation of the audience experience of the works.

5 NEW STUDIES

Photographs and images of the artefacts produced in this study are submitted at the beginning of this dissertation in the form of a DVD and illustrated below in photographs and illustrations. The DVD and illustrations below are to be used as supporting evidence of the inquiry undertaken during the research; however, the two-dimensional representations of the four-dimensional artworks here are included for illustrative purposes only as the images cannot be recorded accurately.

The submitted artworks are the outputs of three phases of the research and include the following;

i. Phase 1: Figures 44-56 illustrate eight abstract animated lenticular works from colour prints depicting different time durations, based on scientific research data.
ii. Phase 2: Figures 58-70 consist of photographs of ten monochromatic analogue holograms depicting family photographs and selected family heirlooms.
iii. Phase 3: Figures 66-67 consist of a digital sketch and photograph of a large format digital animated hologram depicting a four-dimensional family photographic album. The section ends with an analysis of the feedback gathered to determine audience experience of the artwork.

5.1. Phase 1: Temporal depiction in lenticular imaging

Phase 1 results included eight large-format animated lenticular artworks. All the pieces contained vertical lenticules so the images animated horizontally through 24 different diachronic images as the viewer moved from side to side in front of the works. The body of artwork aimed to answer the research question in relation to whether temporally and spatially coherent images could be created in lenticular imaging. The content was inspired by a spectrum of time durations lasting from picoseconds (trillionths of a second), to a period of 49 million years. The work was appropriated from scientific data from photonics researchers and astrophysicists working with photonics and lasers, magnetism, astronomy and particle physics. The images were abstracted by removing the quantitative data element to the images, leaving movement and colour.

The individual images of the lenticulars are followed by photographs of the work being shown in two different exhibitions. The last section includes the results of audience feedback of the works from the survey and critique group.

5.1.1 The artworks

Two different sets of images are shown below to represent the artworks created in Phase 1: the first images are taken directly from the scientific data which illustrate passing time periods, and the second are stills taken from the videos of the artworks which are shown on the accompanying DVD.

Picoseconds 1

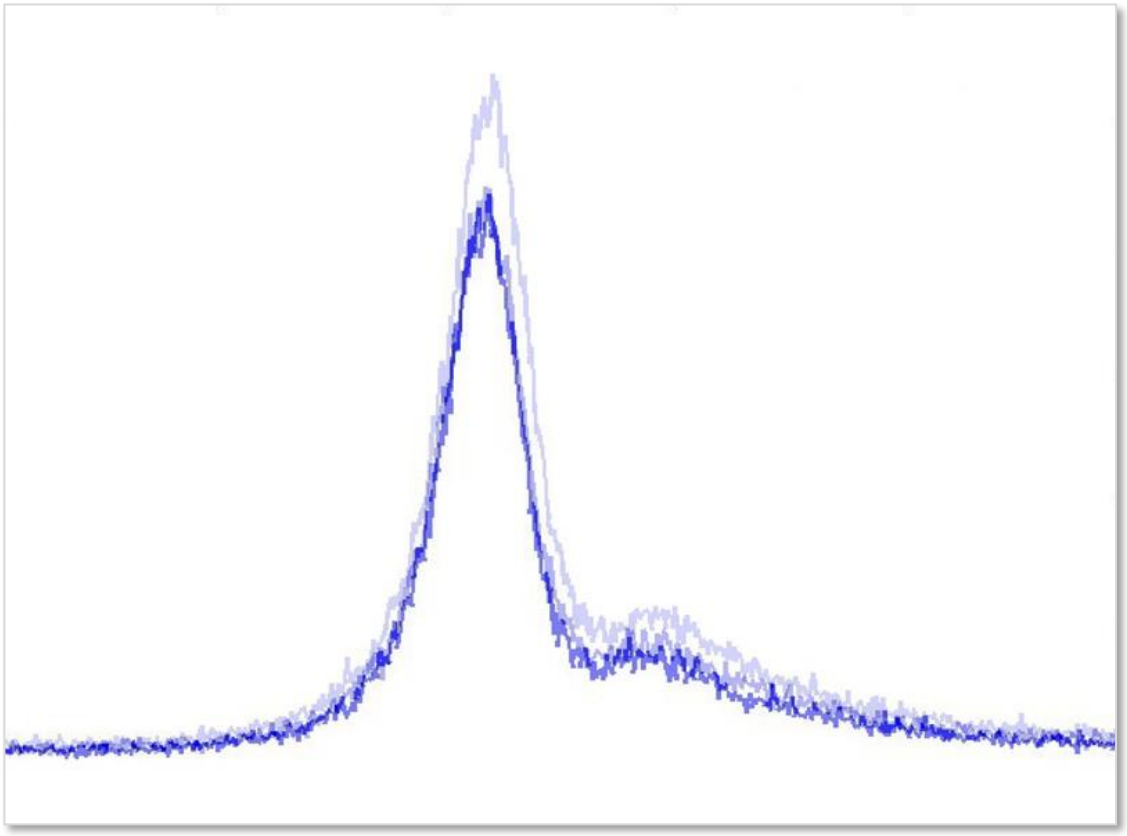


Figure 44. *Picoseconds 1*, detail illustration for an animated lenticular artwork, 30.5cm x 38.1cm, Pearl John, 2012.

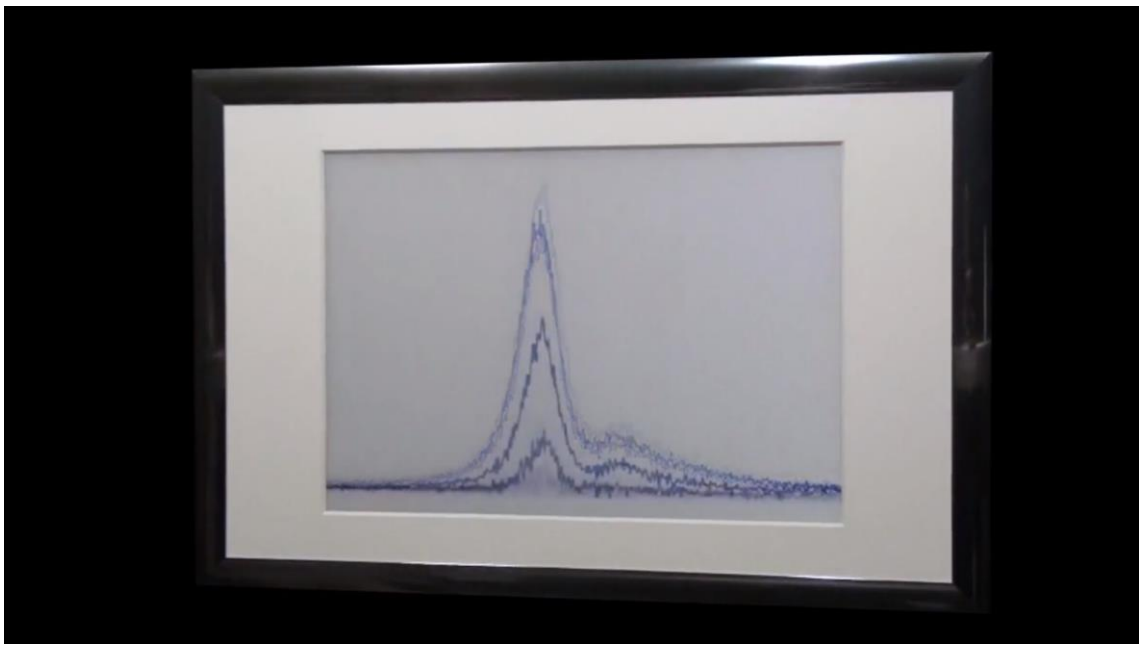


Figure 45. *Picoseconds 1*, detail animated lenticular artwork, 30.5cm x 38.1cm, Pearl John 2012.

Picoseconds 1, shown above in figures 36 and 37, illustrates the concept of temporal coherence; in this the image narrative is the same whether the viewer 'reads' it by moving left to right, or right to left. Whilst the image has a temporal coherence aspect, it lacks three-dimensionality and is therefore not spatially coherent.

The image is impacted by a technical issue called 'ghosting'; different frames can be seen faintly throughout the image rather than a single line. This issue is considered a problem by lenticular designers, but was considered aesthetically pleasing by the author as it emphasises the movement of the image over time, so was retained during the design phase.

The temporal coherence in the image has affective impact and was satisfying to activate. In observing the image, I found myself swaying from side to side repeatedly in front of the work in order to activate the image again and again, and the repetition had a calming effect, despite my being very familiar with the subject matter. I found that the artwork was enjoyable to engage with and motivated a smooth movement backwards and forwards to activate the repetitive motion.

An unexpected result of the work is that, on close inspection, the colour in the blue ink used in the printing is split by the optical action of the cylindrical lenses on the surface of the lenticular into a spectrum of its constituent colours, in a manner reminiscent of the dispersion into different colours of the spectrum as a ray of white light travels through a prism.

Picoseconds 2

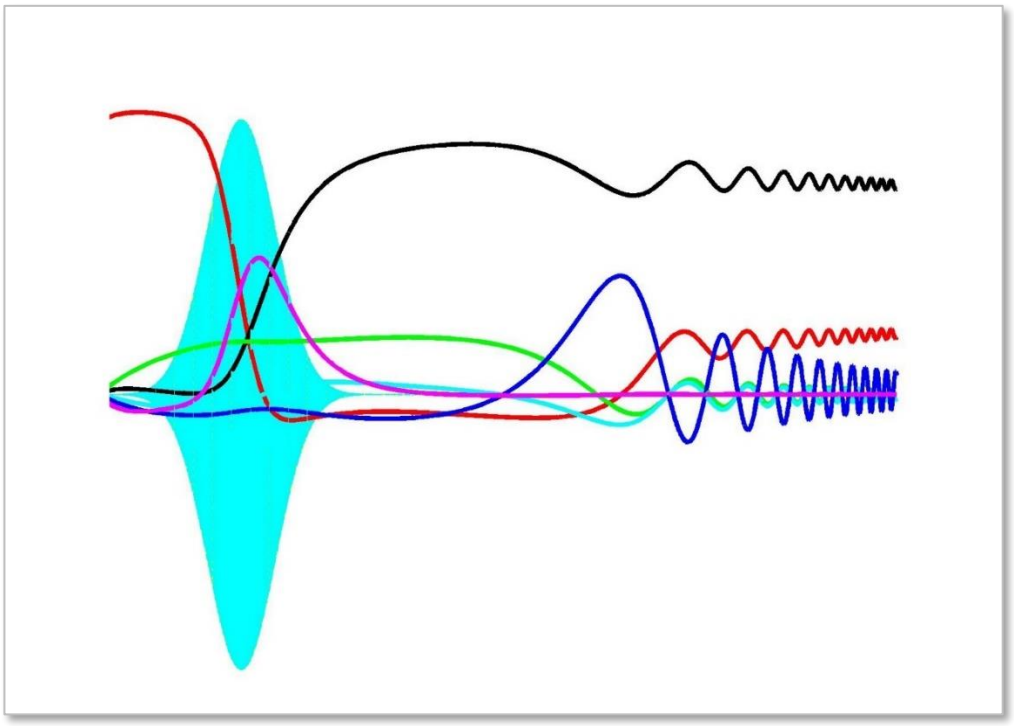


Figure 46. *Picoseconds 2*, detail, lenticular artwork, 30.5cm x3 0.5cm Pearl John, 2012.

Picoseconds 2 is temporally incoherent and is depicted in Figures 38 and 39 above and below. The ghosting effect seen in Picoseconds 1 is apparent again and is as effective in *Picoseconds 2* at emphasising movement changing over time. The image is filled with movements and I found myself adjusting myself very small amounts to observe the lines flowing, changing subtly. The image is reminiscent of a musical score and resulted in my activating it in a non-linear manner.

Figure 47. *Picoseconds 2*, detail, lenticular artwork, 30.5cm x 30.5cm, Pearl John, 2012.

Picoseconds 3

The illustrated artwork below in Figure 40 depicts an abstract flow of colours and movement from the left of the picture to the right. The image is reminiscent of plans of weather patterns, with the movement of an eye of a storm across a land mass.

Nanoseconds 1

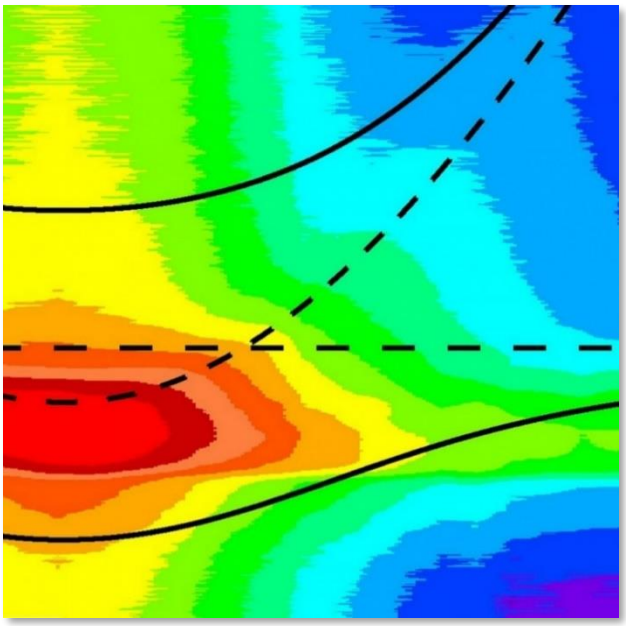


Figure 48. *Picoseconds 3*, detail animated lenticular artwork, 38.1cm x 38.1cm, Pearl John, 2012.

Figure 49. *Nanoseconds 1*, detail animated lenticular artwork, 30.5cm x 38.1cm, Pearl John, 2012.

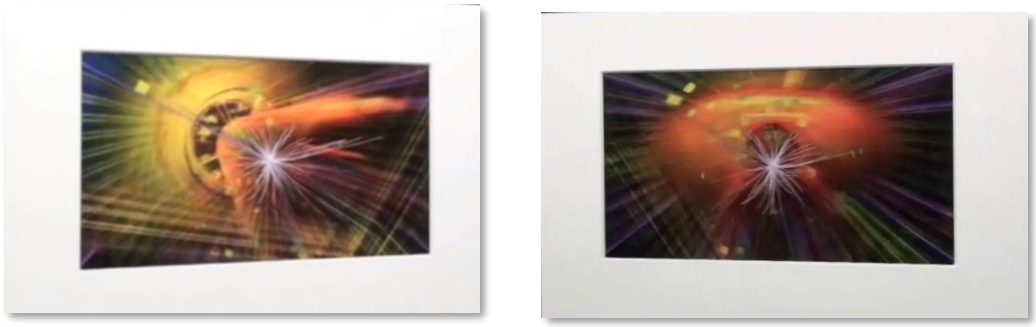


Figure 50. *Nanoseconds 1*, two animated views of a lenticular artwork, 30.5cm x 38.1cm, Pearl John, 2012.

Nanoseconds 1: The four-dimensional image benefits from stereoscopic parallax, a technical aspect described by Pizzanelli in holography, but relatable to lenticular imaging:

> Multiplex holograms present an array of images in a kinematic display wherein the motion and the parallax are combined (1994, p.1).

Lenticular artworks can generally either be three-dimensional or animated. *Nanoseconds 1* is both as the image effectively contains stereo-pairs. The image was appropriated from a short, animated film[23], produced with permission by the CERN Media centre designer

[23] Information regarding the data which the imagery is selected from can be found in the Appendix of this dissertation.

and edited down to 20 images. The central image, a white starburst-like object, hangs in front of the image plane, emphasising a frozen moment in time. The image captured a moment of time in space and was spatially and temporally coherent.

Nanoseconds 2

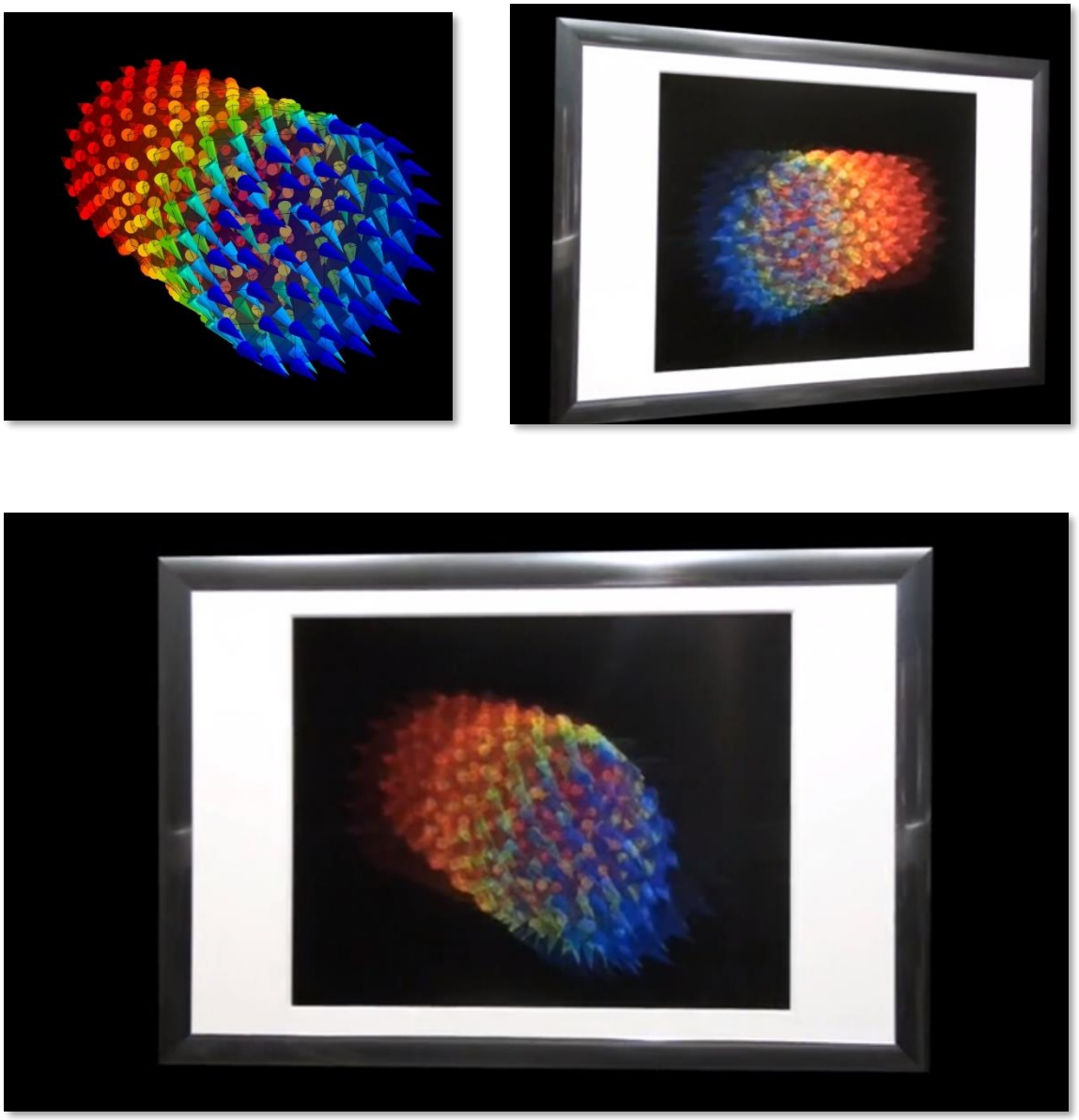


Figure 51. *Nanoseconds 2*, 3 views of an animated lenticular artwork, 38.1cm x 38.1cm, Pearl John, 2012.

Nanoseconds 2 depicts a spinning object. The movement of the viewer causes rotation, encouraging the viewer to activate the image repetitively to try to understand the complex nature of the rotating image. This results in the observer making both slight, subtle movements from side to side to activate the image, and larger movements to operate the object which appears to swing. The image projects forward out of the image plane into the audience's space.

Days

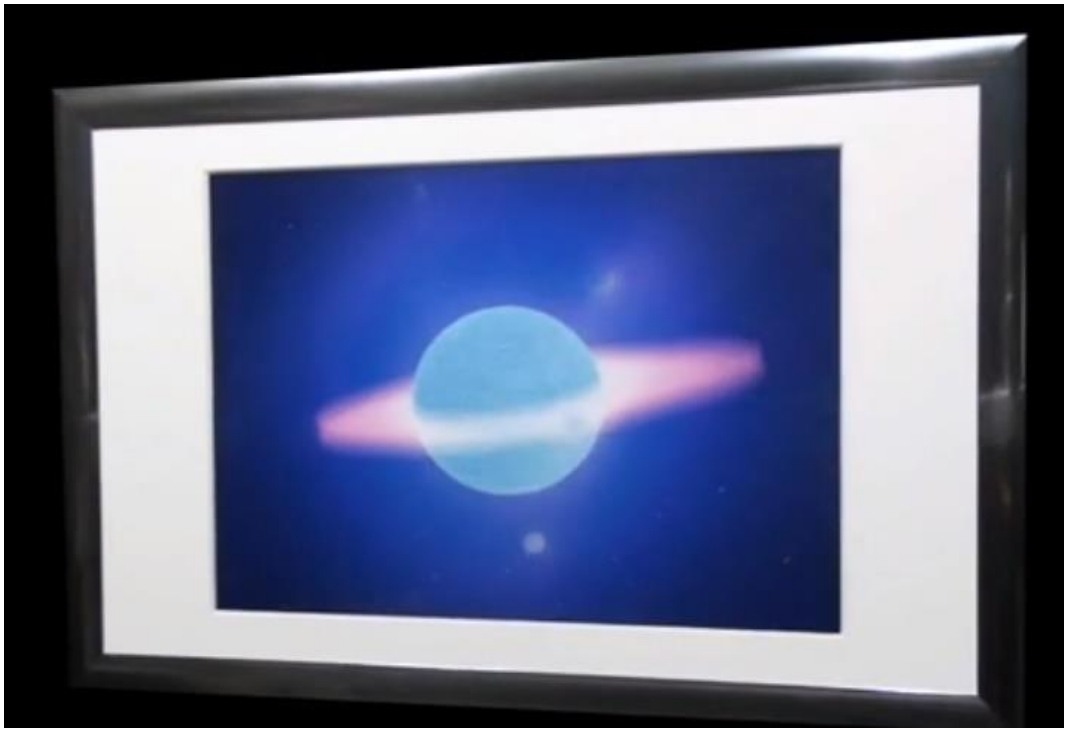


Figure 52. *Days*, animated lenticular artwork, 30.5cm x 38.1cm, Pearl John, 2012.

Days, an image which appeared figurative, exhibited a different kind of 'ghosting'; subject motion, a technological issue in which images appear fleetingly and disappear in a couple of frames. The result of this ghosting is the viewer having to make very small side to side movements of only a few degrees in order to capture the objects depicted. The central object contains depth and detail which results in the viewer wanting to slow the image down to observe the detail more closely.

Aeon 1

The image Aeon 1 contains movement and an apparent depth. The image depicts slices

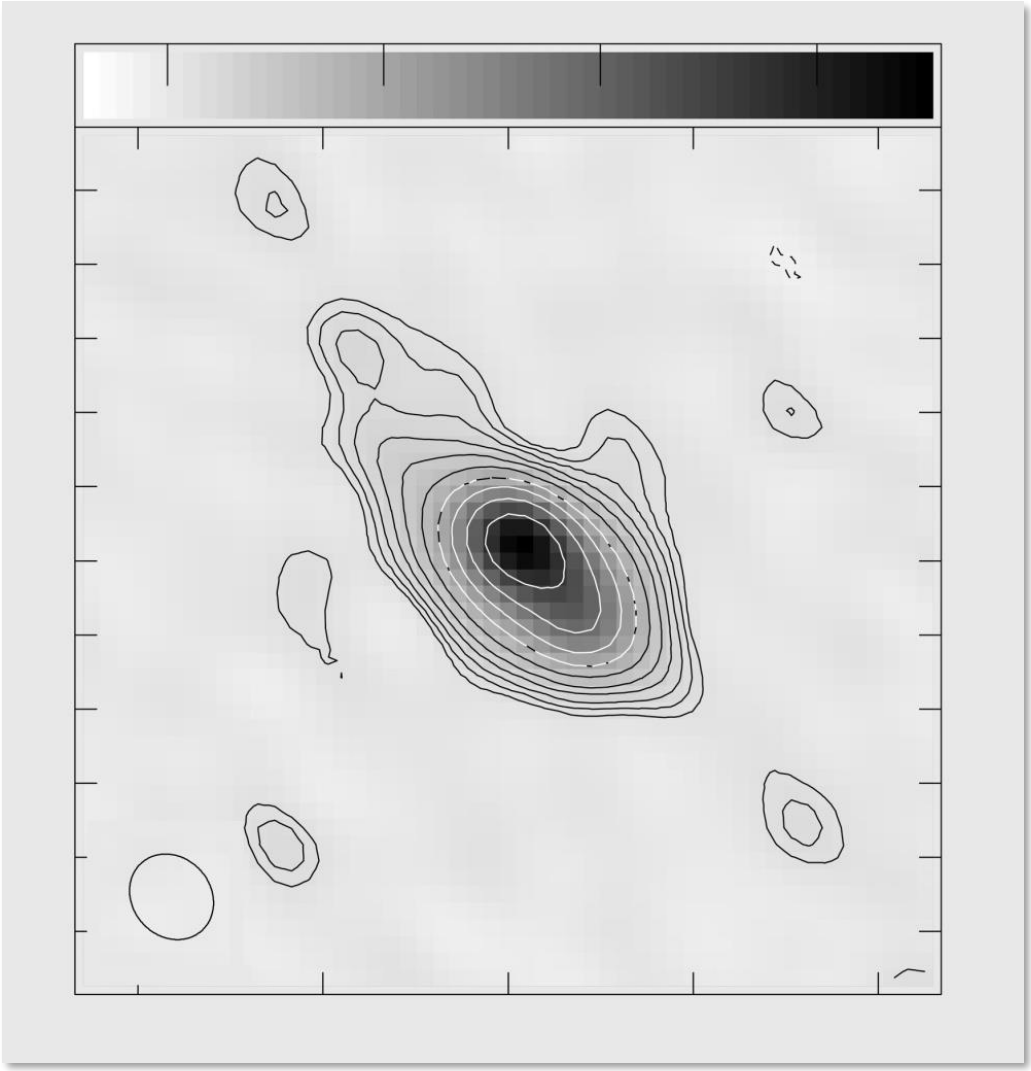


Figure 53. *Aeon 1*, detail animated lenticular artwork, 38.1cm x 38.1cm, Pearl John, 2012.

of time, as each radiating irregular shape is from a different time period. The work is inspired from particles radiating from black hole jets from millions of light years away. The central mass appears to move diagonally across the lenticular and the viewer moves to activate it.

Figure 54. *Aeon 1*, detail animated lenticular artwork, 38.1cm x 38.1cm, Pearl John, 2012.

Aeon 2

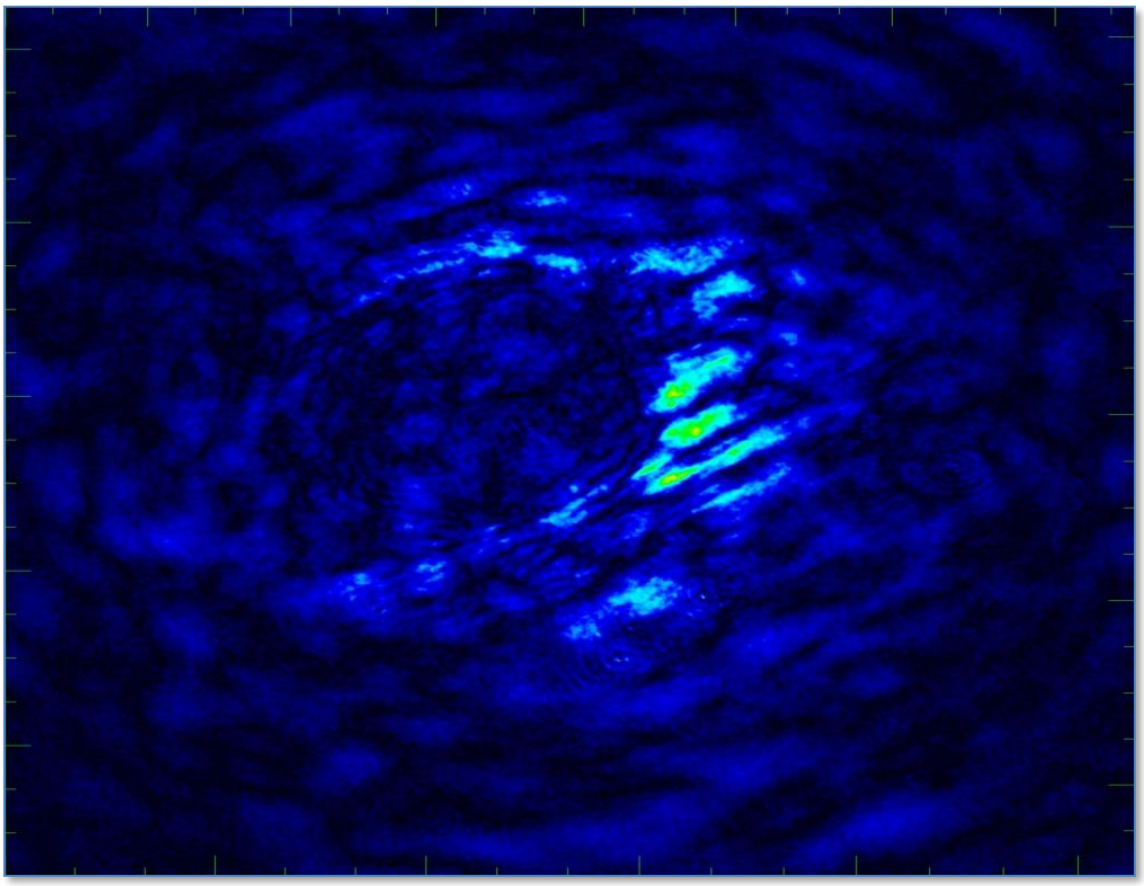


Figure 55. *Aeon 2*, detail animated lenticular artwork, 38.1cm x 38.1cm, Pearl John, 2012.

Aeon 2 illustrates subtle changes in depth in the shadow-like image as the viewer moves from left to right in front of the lenticular.

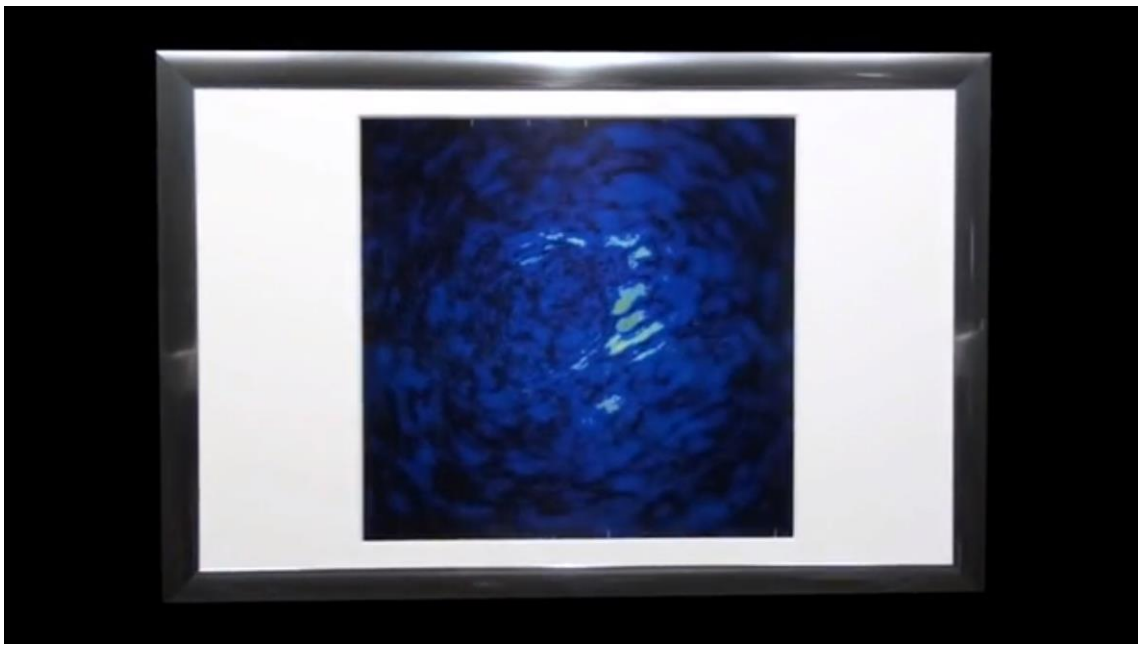


Figure 56. *Aeon 2*, detail animated lenticular artwork, 38.1cm x 38.1cm, Pearl John, 2012.

5.1.2 Installation of artworks in public exhibitions

The photograph below, in figure 57, was taken at the first exhibition of the lenticulars called *In Time* at the Royal Society Summer Science exhibition. Logistical problems prevented a thorough evaluation of the audience's experience of the artwork in that environment, so a further exhibit of the artworks was undertaken at the University of Southampton during Phase 2 of the study.

Figure 57. Installation view of the *In Time* exhibit at the *Royal Summer Science Exhibition*, July 2012. Photograph by Pearl John.

5.1.3 Conclusion of research phase one

The author researched different methods of scientific visualisation of time periods ranging from picoseconds to billions of years. The research involved selection of data; design; testing; and production of the above lenticular artworks. Two of the eight images could be described as temporally coherent, and the remaining six, temporally incoherent. Two of the images were three-dimensional, the rest animated. The affective impacts of the work were discussed in that the viewer was directed by the artwork to move differently in relation to it dependent on the image content. An audience evaluation was completed not at this time, but in Phase 2 and that is described in the next section

5.2 Phase 2: Space in holographic imaging

This section details the second phase of the research project which was designed to answer the question of whether real and virtual holographic space can be used to display images chronologically. The second phase concluded with a public exhibition of the artwork, entitled *A Virtual Artist*, held at the Special Collections Gallery at the University of Southampton's Hartley Library from 26 August 2014 - 26 September 2014. The holograms were exhibited alongside archival objects relating to the content of the images within the holograms. At the end of the section a photograph taken during the private view is included. The last section includes an analysis of the audience experience of the artworks.

The Virtual Artist exhibit includes the artist's own selected 'special collection' of objects and holographic artworks which were gathered to form an archive of a family history. Some elements of the exhibit were autobiographical, while two objects were fictitious; copies of family heirlooms. Ten pseudo-colour reflection holograms were paired with vintage or antique objects. The holograms depicted the artist's family members from different eras. The objects in which the portraits were embedded or associated with – some figurative and some abstract – were themselves from different eras and included; a miner's lamp, a first world-war compass; a Nikon SLR film camera; a necklace; a dinner plate from the 1970s; and a pair of silver-dipped child's shoes. The objects are shown below in figures 37 – 39. All the holograms are mono-chromatic. Green was chosen for its metaphorical meaning in film; 'green symbolizes life, growth and particularly rebirth'

(Dick, 1990, p.103), and for the eye's sensitivity to the colour when exhibited in dark lighting conditions.

The artworks were structured to suggest the design of a family time-line, with a central artwork representing the present time, and ancestors either side of the present moment – which was depicted by a clock, representing different sides of the artist's family tree. This structure of a horizontally structured family time-line was not discernible by an audience, or was not commented on during the evaluation process.

Figure 58. Panoramic Installation view of *A Virtual Artist* exhibition, 2014.
Photograph by Martin Richardson.

Figure 59. A Virtual Artist installation view, 2014. Photograph by Rob Luckins

Miner's Lamp: Great-Great-Grandfather

Figure 60. *Miner's Lamp: Great-Great-Grandfather*. mixed media with reflection hologram, 10cm x 25cm, Pearl John, 2014, Photograph by Rob Luckins.

Miner's Lamp: Great-Great-Grandfather (2014) consists of holographic text physically overlaying the object mounted in a Perspex frame designed to present texts in the museum. Because the text is situated in the virtual space behind the frame the holographic image virtually embeds itself into the object. The text narrative describes the real story of a mining disaster that a distant relative had been involved with. The lamp used in the

artwork was not authentic. The actual lamp that the story was based on was owned by a relative and considered too precious to use in the exhibition, so a replacement was purchased. While the historical narrative was personal to my family, the lamps are common antiques, especially in families whose ancestors were involved in the mining industry. The lamp was selected as a suitable object to be placed in the museum environment. The text was not visible to all audience members; however, it was hoped that the viewer would discern that the lamp contained a story.

The New Clock: Self-Portrait

Figure 61. *The New Clock: Self-Portrait*, mixed media with reflection hologram, 20cm x 30cm, Pearl John, 2014.

The New Clock: Self-Portrait (2014) depicts text on the surface of a new clock. The inclusion of the clock in the installation of works was designed to draw the audience's

attention to the temporal aspects of the work, and to the present moment. The clock was moving, the bottom of the clock rotating backwards and forwards in a manner reminiscent of a clock with a mechanical pendulum.

Boxer Sketch: Grandmother

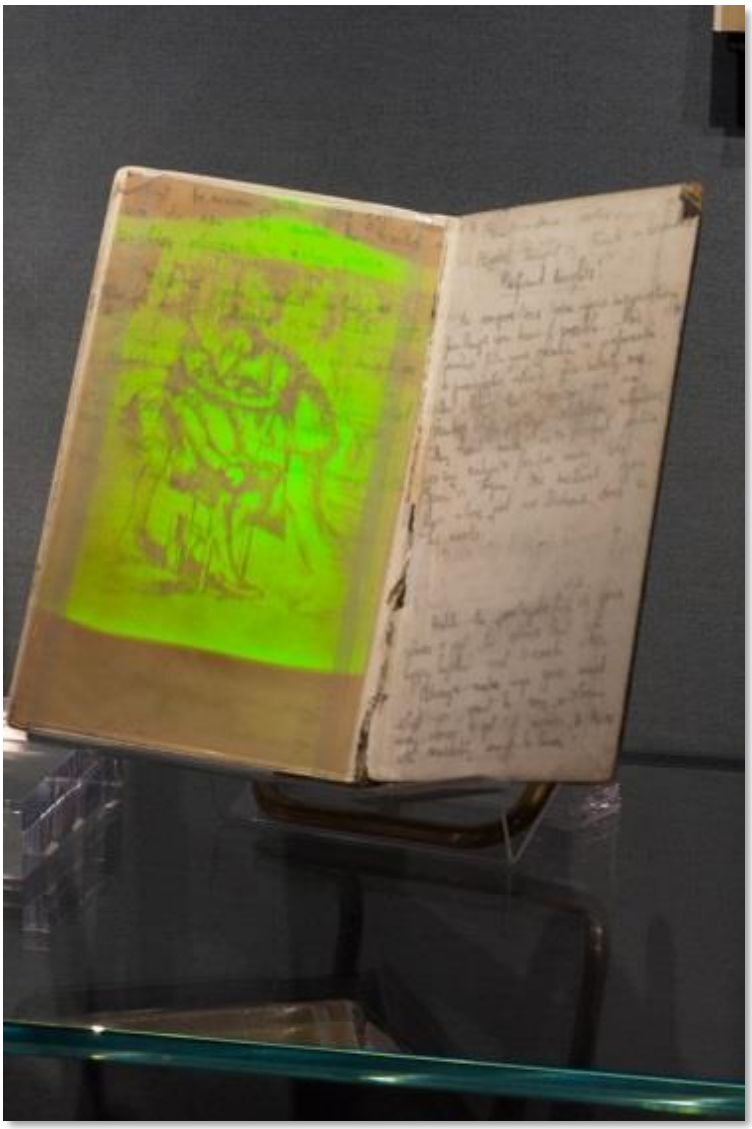


Figure 62. *Boxer Sketch: Grandmother,* mixed media with reflection hologram, 20cm x 25cm, Pearl John, 2014.

The Boxer Sketch: Grandmother (2014) depicts a holographic sketch overlaying a page from an artist's open sketchbook. The page text adjacent to the hologram, entitled

‘Profound thoughts’, describes the process of drawing and creativity. The sketch depicts a fighter recovering between rounds.

Dinner Plate: Mother

Figure 63. *Dinner Plate: Mother*, mixed media with reflection hologram, 25cm x 25cm, Pearl John, 2014, Photograph by Rob Luckins.

The image sunk into the dinner plate depicts a photograph of the Queen with a child in *Dinner Plate: Mother* (2014). The objects are from different time periods: The era within the photograph is the 1950s, judging by the age of the Queen, and the plate and cutlery

are from the 1970s. The object and hologram suggest an unknown narrative that lasts over decades.

Silver Shoes: Sister

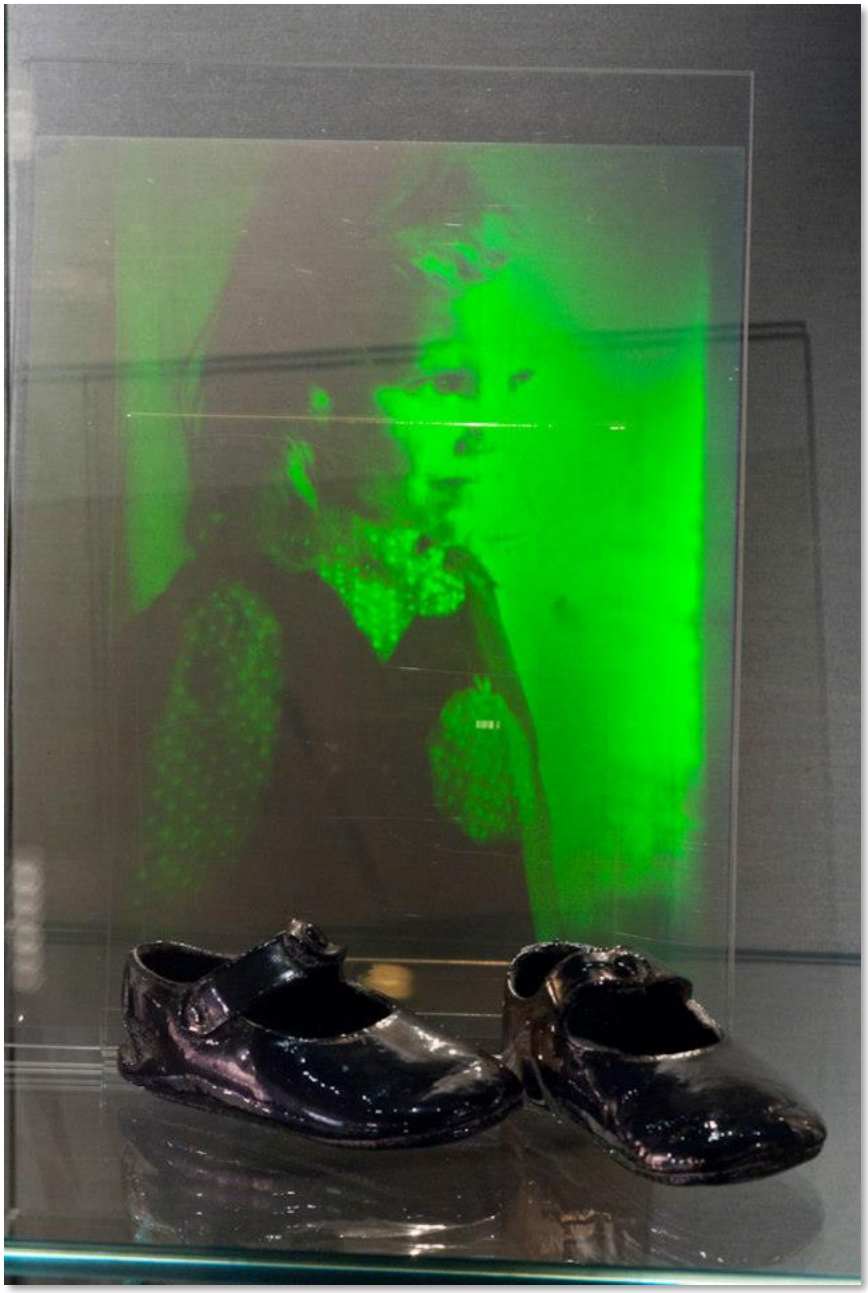


Figure 64. *Silver Shoes: Sister*, 25cm x 30cm, mixed media with reflection hologram, Pearl John, 2014, Photograph by Pearl John.

Silver shoes: Sister (2014) depicts a hologram of a photograph wearing clothing from the 1970s. The image has an air of nostalgia as the child faces towards a window looking outwards into the space behind the edge of the hologram. The hologram is presented to the viewer in a perspex frame used to present precious documents in the museum. The transparent framing emphasises the emphemeral nature of the medium and is contrasted by the objects placed in front of the hologram; the silvered child's shoes are a vain attempt to solidify a moment in time by encapsulating it with precious metals.

The Compass:Great-Great Grandfather

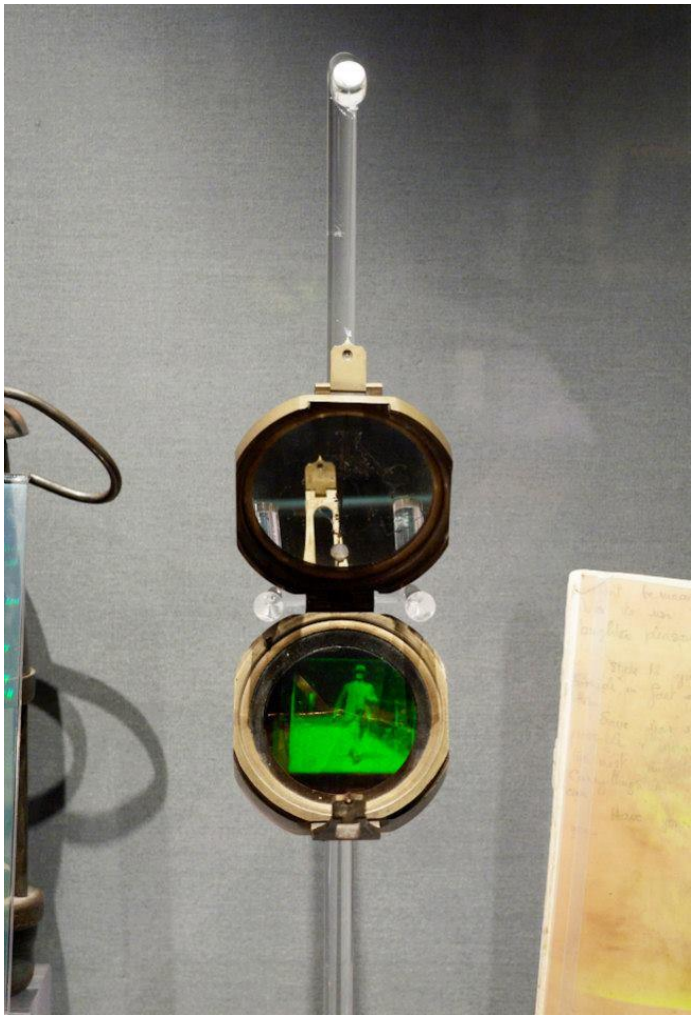


Figure 65. *The Compass: Great, Great Grandfather*, mixed media with reflection hologram, Pearl John, 2014.

The Compass:Great-Great Grandfather (2014) depicts a compass from the First World War and contains a hologram of a man, dressed in clothing from the 1940s, striding purposefully toward the camera and carrying a walking stick. The object was presented in the cabinet hanging from a transparent wire held by a perspex mount. The copy of the photographic image was sunk into the compass, in line spatially with the mechanism of the compass.

The Camera: Father

Figure 66. *The Camera: Father*, mixed media, reflection hologram, 20cm x 15cm, Pearl John, 2014.

The Camera: Father depicts a camera from the 1980s, containing an image taken from a newspaper. The words in the crossword describe different aspects of image making and technical photography and holography, including reflection, refraction and other words providing answers to the meaning behind the work.

Great Grandmother: Portrait

Figure 67. *Great Grandmother: Portrait*, reflection hologram and digital print, 12.7cm x 15.2cm, Pearl John, 2014.

This artwork depicts two portraits of the same woman. The holographic portrait is transparent and overlays the digital photograph. The hologram contains a distance in the

Z axis enabling the overlaid image to sink behind the surface image. The space inside the frames illustrates approximately 40 years difference between the two portraits. The artwork is framed in a contemporary frame reminiscent of a 1950s style. While the image is not animated, the meaning of temporal and spatial coherence is most clearly evident in this work.

The Necklace: Aunt

Figure 68. *The necklace: Aunt*, mixed media with reflection hologram, 20.3cm x 25.4 cm, Pearl John, 2014. Photographed by Rob Luckins.

The Necklace: Aunt (2104) pairs an antique ‘Mother of Pearl’ piece of jewellery presented on a velvet stand, with an analogue hologram of a photograph of an actress’s head-shot from the 1950s. The holographic image is sunk into the velvet stand behind it and appears to unite image with object.

The Wedding Photograph: Grandfather

Figure 69. *The Wedding Photograph: Grandfather*, reflection hologram, 15cm x 20cm
Pearl John, 2014. Photographed by Rob Luckins.

The Wedding Photograph: Grandfather (2014) incorporates a hologram of a photograph with the camera that took the image. Having two cameras from different decades in the same cabinet encourages the viewer to consider that picture-making technologies from different time periods are being referenced.

5.2.1 Phase 2: Exhibited works

Figure 70. *A Virtual Artist* Installation view, 2014. Photograph by Jane Birkin.

The Special Collections Gallery, where the analogue holographic artworks were shown, normally houses the University of Southampton's archive of the Duke of Wellington's collection of letters, and historical memorabilia. The exhibition programme usually focuses on themes of artefacts within the collection and relates to University academic activity such as celebrations of research, conferences and contributions to national and international event. The gallery is a museum-grade conservation environment and incorporates a temperature-controlled vault with missile-proof cabinets and low LED lighting designed to protect exhibited works. The venue has a sense of gravitas; this benefitted the artworks and had an impact on the audience and their viewing of the art. This was as evidenced in audience feedback which is described in the next section.

The *In Time* exhibit created in Phase 1 of the research project was exhibited for a second time during the Virtual Artist show in the Hartley library Level 4 Gallery which was

adjacent to the Special Collections Gallery. The exhibition view is shown in the photograph, figure71.

Figure 71. Installation of the *In Time* lenticular artworks exhibit at The Virtual Artist Exhibition, 2014. Photograph by Pearl John.

5.2.2 Phase 2: Evaluation

Approximately 500 people visited the exhibition. 71 audience members attended the private view and were contacted three months after the event via email with an invitation to take part in an on-line survey. 23 responded. Both Phase 1 and 2 artworks were evaluated by two different audiences. Audience feedback was gathered by two different methods: an on-line survey and a critique session by professional artists. Chapter Three, section 3.7, describes the methods used to gather feedback, along with limitations of the methods used.

5.2.3 Phase 2: Feedback Survey results

The survey questions asked for the following information: basic demographics regarding gender[24] and age, frequency of visits to galleries, reasons for attending the exhibition. Participants were also asked about their previous experience of visiting art exhibitions

[24] In future surveys this will include more than male/female options for participants to choose.

and a marketing question to determine how they had heard about the exhibit. The participants were also asked what they felt/thought about what they had seen. The questions can be found in the Appendix to the dissertation. Answers to the questions determined that 59% respondents were female and 41% male. 62% of the respondents described themselves as aged over 51 years, with no attendees under 18 years old.

Answering the research questions

The audience were surveyed to determine whether (a) they could perceive the depth within the holographic images as relating to the past; (b) whether they had had a new experience; and (c) whether work had affective impact. Survey question 8 asked**:** "What did you think/feel about the artwork that you saw in the exhibition?' The answers to that question are shown below in relation to the research questions:

a. One audience member noted the temporal and spatial aspects of the artwork:

   'Seeing layered imaging showed me a partial observation from a multi layered view' (Viewer 1) and two audience members referred to the connections between the holograms and the objects: 'the holograms that were blended with family heirlooms were particularly evocative' (Viewer 14); 'I think that the use of personal objects for mounting holograms was very interesting and unique' (Viewer 22).

b. Three audience members commented specifically that they had not seen work like that exhibited before;

   'Inventive and imaginative' (Viewer 15); 'the use of personal objects for mounting holograms was very interesting and unique' (Viewer 22); 'It was original and a totally different type of art in comparison to the usual exhibitions I attend' (Viewer 23).

c. Audience members described the work as 'fascinating' (4) or 'interesting' (5). Other comments included; 'inspiring', inventive', and 'amazing'. 26% of the respondents said that they had never been to an art and technology exhibit before, and a further 21% had only been to one exhibition with art and technology. The fact that art and technology exhibitions are rare, and that exhibitions that use holography as an art media are even rarer, suggests that this audience had indeed had a new experience.

d. Audience responses demonstrated that the artwork had had an affective impact:

> 'I found the pieces moving, beautiful, thought provoking, exciting' (Viewer 2); 'very creative and fascinating' (Viewer 3); 'the holograms that were blended with family heirlooms were particularly evocative' (Viewer 14).

Many more responses indicated that the work had had an emotional impact on the viewers and included comments such as 'touching', 'connecting with', and 'engaging'. Illustrations of audience responses in the form of analytic and affective word clouds are shown below in figures 72 and 73.

Figure 72. Affective survey responses

Figure 73. Analytic survey responses

An unexpected response

53% of the respondents declared an interest in physics and astronomy, and audience members reported appreciating the art science connection in the lenticulars between the images created and the concepts communicated:

> 'It was really interesting to see scientific ideas rendered within an artistic context'; 'a stimulating synergy between art and science, in which both components benefitted'; 'the science component was very beneficial for me in keeping me looking for longer'; 'opened my eyes to the intersection between artwork, astronomy, physics, [and] technology'.

5.2.4 Phase 2 evaluation - a silent researcher critique with professional artists

Three professional artists took part in a silent research critique with the author to evaluate a selection of artworks produced in Phase 1 and Phase 2 of the study on 3 October 2014. The aim of the evaluation was to (a) determine whether the audience could perceive temporal and spatial coherence in the artworks, and whether the work gave them a (b) new, (c) authentic experience with (d) affective impact.

a. Temporal and spatial coherence

The artists were aware in part, of the intended themes relating to time and space within the artwork:

> 'I think what I imagined when I saw them [the holograms] in the gallery was that they were dealing with layers of memory. (Artist A); 'similar intention in speaking to your audience about perhaps illusiveness, memory, time' (Artist B); 'the process you use is about movement' (Artist C).

The artists recognised that the images were layered and that movement, in the form of interactivity, was an important aspect of the work. The themes of memory and time were recognised. However, the use of the Z axis to represent chronological time was not obvious to the artists.

b. A new experience

One of the artists spoke of my being the only artist they knew working with lenticulars and holograms: 'You're the only person I know using them in this way' (Artist A). Another knew of one other artist (Bashir Makhoul) who had used lenticulars. This lack of familiarity with the medium suggested that they were having a new experience with the media.

c. Authenticity

The evidence for authenticity lies in the ability of the artwork to make the viewer aware of being 'in the moment'. One artist in particular referred to the indexicality of the work and a frustrating sense of nearness and distance:

> 'So, you stood in front of one [the holograms] and there it came alive – and then you went to the next one and there it came alive' (Artist A); 'what I can discover by - by finding that moment?' (Artist B); 'people were really peering and spending time in a very lovely way' (Artist A).

> that indexicality and distance that you seem to curate in the work…there was all these layers separating, and then it would move, [laughter] and it was then - right, I've got it, but you have to kind of hold your breath, then it was gone. (Artist B)

Lastly, one artist spoke of the idea of an object containing memories:

> 'you always feel – don't you – when you pick up an old necklace that your Mum wore, or somebody wore, that feeling of the person there, in it, but you haven't got them there' (Artist A).

d. affective response

The audience felt that the exhibited artwork made them feel frustrated, maudlin and nostalgic, but claimed that the engagement was also pleasurable:

> 'frisson of frustration and tension of inaccessibility…It was very cathartic too"' (Artist B); 'Nostalgic' (Artist A); 'it was very maudlin and it made me feel maudlin and I quite enjoy that as well' (Artist B); 'I was sort of swaying backwards and forwards in front of this one which is very, very pleasurable' (Artist C).

Unexpected results

One artist was unable, when describing the works afterwards, to remember the difference between a full-colour lenticular and a monochromatic hologram, which the author found shocking. This was no doubt as a result of the artist being unfamiliar with both media. I had been concerned that the artists would not be able to see the links between the two phases of the study, but two of the three artists saw the connections between the artworks across the two different media: 'I didn't seem them as actually separate' (Artist C); 'I thought that there was a connecting narrative between the two' (Artist B).

5.2.5 Phase 2: Conclusion

Phase 2 of the study involved making ten analogue holograms, exhibiting them, and evaluating them. Analogue holography had been chosen as the preferred medium to produce images with more depth in them than lenticular imaging could provide. Both the analogue holograms and lenticulars produced in Phase 1 were evaluated using two different methods: an on-line survey of members of the public, and a critique session with professional artists. The audience survey results provided evidence that the public audience had a new and affective experience in seeing the artworks. However, there was no suggestion that those unfamiliar with art and technology had been able to perceive the conceptual aspects of the research study. The professional artists were more able to discuss the spatial aspects of the work, but they too were unable to verbalise how the works were using space. This was both a result of being unfamiliar with the mediums used, and perhaps of the subtlety of the works, which used a limited amount of depth in the images. The next phase of the work led to my using different techniques and evaluating the works with a group of experts, familiar with the techniques I was using.

5.3 Phase 3: Temporal and spatial coherence

This full-colour digital animated artwork depicts a 4-D family album. As the viewer moves from left to right in front of the artwork, photographs move to occlude the photograph behind it, mimicking a camera rotation. The photographs were selected for their formality and their similar compositions, although one photograph was flipped to ensure that the bride was shown to stand on the right. The film on the righthand side was on a loop to avoid issues of reversibility.[25]

Figure 74. Detail Passing time, a distant memory, digital animated hologram, 65cm x 25cm, Pearl John, 2018.

[25] It was important that the marriage ceremony didn't appear to be 'un-done' as the viewer had the potential to reverse the image.

Figure 75. Detail Passing time, a distant memory, digital animated hologram, 65cm x 25cm, Pearl John, 2018.

5.3.1 A Visual Explanation of Temporal and Spatial Coherence

For those unfamiliar with holography the Z axis of holographic space is difficult to describe. In order to more accurately describe the results of the research a video definition of Temporal and spatial coherence has been created and presented in the DVD which accompanies this dissertation.

> "This is a brief introduction to the z-axis of holographic space and how I've used it to depict different time periods. As you'll see from the left-hand side of the Hologram this depicts an image further back in time and farther back in the hologram. As we move from left to right the holographic image comes closer to the plane of the surface of the Hologram and each photograph comes closer to the present." (John, 2018).

5.3.2 Phase 3: Audience feedback methods

Audience feedback was gathered via a 25-minute silent researcher critique session run with nine international experts, or peers (Costello, 2009) in art and holography. Three men and six women took part in the research process, signing forms to agree to take part in the research project. The group included two Canadians, two Americans, one Taiwanese artist, one Portuguese artist and two Australians and one British artist. The session was filmed by a colleague from De Montfort University. The audio file was transcribed by professional transcription service UK Transcription. The transcription was

checked and edited by the author to ensure that it was an accurate representation of the critique session.

The transcription was also checked by the film-maker, who declared; 'the transcript correctly describes the discussion and individual contributions. (Dalenius, 2018).

The transcription was prepared by the author to ensure anonymity of the speakers and uploaded into NVivo. Open and closed codes were created by the author using descriptors and NVivo phrases and checked by Dalenius. Themes were created from the coding using a general inductive approach (Thomas, 2006). This approach was considered appropriate as it enables data analysis to be guided by evaluation objectives.

5.3.3 Results

The work was evaluated to determine whether the artists could understand the concept that the Z axis of holographic space was depicting chronological time; whether the viewers had a new experience in viewing the work; and whether it had authentic, affective impact.

The experts thought that the artwork was novel, depicted images and memories within holographic space in a new manner, and had affective impact:

> 'A new way to present the past' (Expert I); 'You are sinking memories into holographic space' (Expert G); 'I felt sad when I looked at the image' (Expert A).

The audience of experts recognised that they were part of the time line and that the Z axis of holographic space included their own present time and space:

> "…if we're thinking we're dealing with a timeline are we were part of that line by viewing the work?" [Laughter](Expert B); 'Okay. I mean it's about this moment. It's about this very particular moment' (Expert D).

The experts discussed different concepts of time inherent in the work I had produced, and included our felt experience of time and our concept of linear time. Despite not having seen the lenticular images created in Phase 1 of the study, the experts discussed physics.

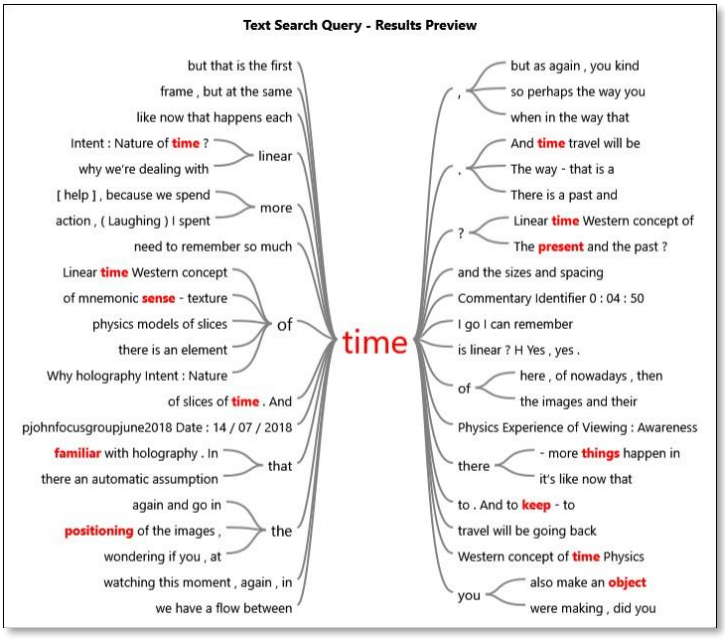


Figure 76. Illustration of critique session discussion relating to time

Emotional impact

The emotions that the participants reported included sadness and nostalgia. However, during the discussion, other aspects became evident. There was discomfort evident relating to two different aspects of the discussion: the first related to authenticity, and the second to metaphysics. Two experts expressed that they distrusted that the family history presented was authentic. A sense of tension during the silent researcher critique was relieved with laughter when there was a suggestion that the family presented was not mine and that the narrative was inauthentic. In discussion with Dalenius, she explained she thought that this was as a result of the audience questioning their own assumptions that the work was a personal history. Another area of discomfort was due to three of the experts disagreeing with one another regarding issues of metaphysics and physics. Two participants shared concepts of objects containing memories, or the essence of the person that they related to. One expert jokingly referred to as the objects containing ghosts, and another, rooted in science, firmly disagreed. Two artists in the Phase 2 evaluation had discussed the same issue of objects containing memories; however, the artwork does not contain many memories for the artist, most of the photographs having been taken before I was born. Instead, the photographs suggest memories, someone's memories.

5.3.4 Conclusion of Phase 3

In evaluating audience responses to the work by the public and professional artists in Phase 2, it became evident that participants' inexperience with the media influenced their ability to read the work. The audience either could not perceive differences of depth within the holograms, or just did not refer to them in the questionnaire responses. The depths were too subtle to be comprehended. The author adapted future artworks to greater depth in the Z axis in order to make the spatial aspect of the work more evident to the viewer.

The evaluation of Phase 2 by professional artists led me to choose experts in art and holography for the final element of the research as the media were so unfamiliar to professional artists. One of the three who took part was unable to recall the different between monochromatic static holograms and full colour animated lenticulars – which recalls the problems that Benyon encountered when first showing holographic artworks.

5.5 Results Summary

This chapter has described the results of the study. Nineteen works of art have been produced and exhibited; eight large-format lenticulars, ten analogue reflection holograms and a digital animated hologram. The works produced in the study have been evaluated by myself and three different audience groups; the general public, professional artists and a group of art/holography experts. The aim of the evaluations was to determine whether the research questions have been answered. The next section will analyse the results of the study.

6 ANALYSIS

This chapter analyses and evaluates the results of the study. Firstly, temporal and spatial coherence has been achieved and demonstrated in the artworks illustrated in the previous chapters. Secondly, the new aspect of lenticular and holographic space which uses the Z axis of space in the artworks to depict a time-line has been communicated to its audiences who have had a new experience. Lastly, the artwork has had authentic, affective impact. The analysis of the work has been determined by means of observation, analysis of audience questionnaire responses and analysis of two critique group transcripts. Those involved in providing the evidence for the analysis have included the artist; members of the public; professional artists; and artists working with holography. This analysis will provide evidence of the study's contribution to knowledge.

6.1 Temporal and spatial coherence

Temporal and spatial coherence was achieved in different aspects of the artworks. Temporal coherence was illustrated in the lenticulars, and the holograms which sunk memories into objects depicted ways in which time was presented in holographic space. According to Joseph O'Connor and John Seymour, time in Western Society is visualised linearly, with the most distant memory imagined on our left-hand side, and the most recent, and clearest memory imagined to the right (1990). *Passing Time, a Distant Memory* figure 66, illustrated above on page 110, depicts this concept of accessing memory. The image depicts layers of temporal tenses, linking the layers to our lived experience of time passing. One expert described *Passing Time, Distant Memory* as 'stacked up images in space' (Expert I, 2018) The structure of the hologram mimics the way that we visualise our memories in our mind's eye.

Including a geometry of time, as well as space, restores time to the graphical definition of holographic space as defined by Pepper in 1989. We cannot have space without time. The diagram below illustrates the concept of temporal and spatial coherence which has been demonstrated in this study.

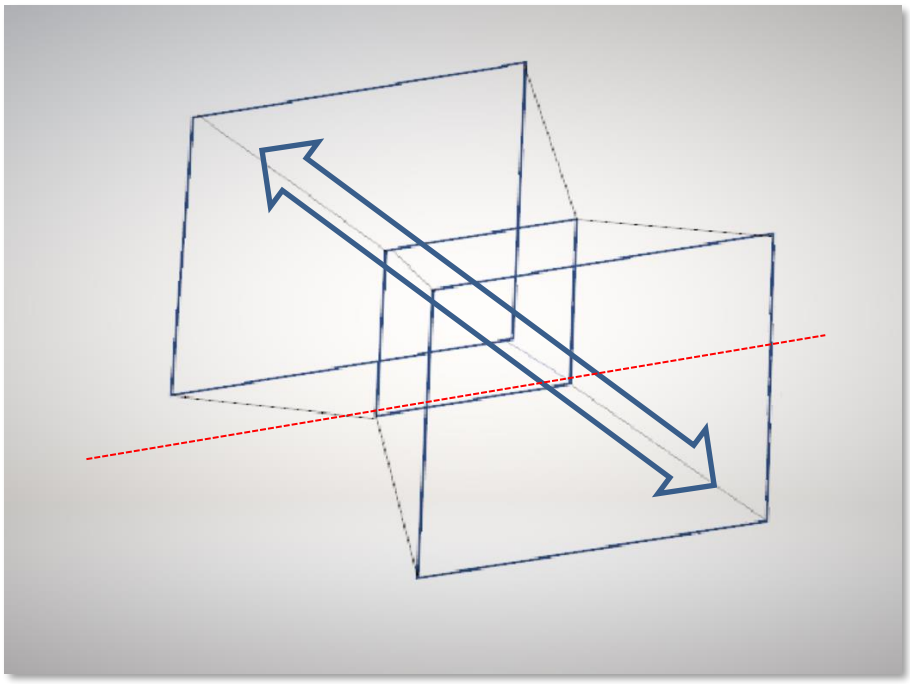


Figure 77. Depiction of Z Axis including a time arrow. The dotted line depicts the present.

The diagonal arrow depicts the Z axis of holographic space, and the red line the plane of the holographic or lenticular image and the present time.

6.2 Communicating the concept to an audience

In *3-D: History, Theory and Aesthetics of the Transplane Image*, Jens Schröter quotes the philosopher Bernhard Waldenfels, claiming that transplane images bring the viewer's attention to the act of looking: transplane images make visibility visible as well. (2014). This was found to be the case with experts used to looking at and working with holographic art, but was not so evident with other audiences. The evaluation revealed that those new to seeing the media of lenticular and holography in a creative context were less likely to describe their engagement with the works conceptually and more likely to discuss their affective responses. Audiences unfamiliar with holography respond more to the medium than the content, an issue that was noted by Benyon during her first few years of exhibiting holographic artworks:

> "The reaction of most people on their first look at a hologram is one of astonishment and occasionally disbelief…" (1973, p.2).

Benyon identified the 'wonder effect' as an impediment to deeper engagement with the medium:

> ‘in our culture a sophisticated awareness of three-dimensions is undeveloped’ (Benyon, 1973, p.2).

43 years later, this was still found to be the case, presumably because of the general public having too few opportunities for viewing holographic artworks.

6.3 A new experience

A good portion of the general public quizzed on their responses to the artwork in phase two of the phase had never been to an art and technology, or a holography, exhibition. There are so few artists working with holography[26] and lenticular imaging[27], and so few opportunities to see holographic, or lenticular, artwork[28], that claiming that the audience had a new experience when viewing the artworks is straightforward: ‘It was original’ (Viewer 23). However, further evidence that the audience had had a new experience was provided by the professional artists and the art/holography experts: ‘You’re the only person I know using them [lenticulars] in this way’ (Artist A); ‘[This is] a new way to present the past’ (Expert I).

The artwork *Passing Time, Distant Memory* (John, 2018) incorporates a new way to store family photographs. Family photographs and films have also not been previously depicted in digital holography; the medium is so new that very few artists have yet had the opportunity to experiment with it.

> …photographs had gradually come to be understood as memory capsules, vessels of short stories, and bearers of coherent narratives. (Pasternak, 2015, p.437).

[26] In *Holographic Visions* (2006, pp.309-310), Sean Johnston reported that while it was not possible to determine an accurate number of artists working with holography, the *Holonet* website (on which I featured) listed just over 200 in 2002.
[27] There are no statistics available for the number of artists using lenticular imaging.
[32.] The holography collector Jonathon Ross’s private gallery Gallery 286 in Earl’s Court, London puts on at least one exhibition of holographic artworks annually to a limited audience.

The animated holographic image *Passing Time, Distant Memories* not only acts as a memory capsule for individual photographs, but encapsulates the capsules. The coherent narratives within the photographs are themselves coherently stored within the depth of the hologram. Multiple narratives held within the featured family photographs and film, in a coherent sequence. The digital hologram adds an extra dimension, a spatial dimension, to the concept of a photographic memory capsule. Sontag had argued that photography was a more memorable medium than film:

> Photographs may be more memorable than moving images, because they are a neat slice of time, not a flow… Each still photograph is a privileged moment turned into a slim object that one can keep and look at again. (Sontag, 1977, p.17-18).

Digital animated holography sits between these two media and records 'slices of times'. While the digital images are described as time capsules, they are not destined to last long; digital holograms bear the same fate as other silver halide-based materials[29] which have undergone a bleaching process, in that they are not archivally secure. Making holograms of film and photographs does not protect them. Analogue and digital photographic, lenticular and holographic images, will all fade over time; attacked either by ultra-violet light, which bleaches analogue photographs and the printing inks used to produce digital photographs and lenticular images, or blackens the analogue and digital holograms as a result of printout, or bacteria which damage the gelatine which secures the silver halide to the holographic film or plates.[30] The idea that photography, or lenticular imaging, or holography, can store memories, is an illusion. The emotive impact of the loss of precious family photographs of lost relatives is the same. Kodak's promise of protecting memories and experience was a falsehood.

[29] Other types of holographic recording materials do last longer but cannot be used for reflection holography, only rainbow coloured transmission holograms.

[3] In *Silver-Halide Recording Materials: for Holography and Their Processing*, Hans Bjelkhagen writes:

> Another problem unique in holography, is the printout effect occurring in bleached silver-halide emulsions…Under the worst conditions the hologram can degrade within less than a year, while under benevolent conditions it can last for many decades. (2013, p.315.)

6.4 Affective impact

The research question asks whether the work has is authentic and has affective impact on the viewer. Affective impact in this instance relates to the physical movement of the audience members in response to interactive artworks, and their emotional responses to the works.

6.4.1 Physical engagement

The audiences' physical engagement with the artworks was determined by the author's observation, particularly with the animated works. The image content determined the viewer's movement, speeding them up and slowing them down in order to respond to the images contained in the works.

6.4.2 Emotional engagement

The three different audiences who evaluated the artworks reported a range of feelings from engaging with them: fascination, interest, frustration, sadness, enjoyment. Audience members described the work as moving, exciting, haunting, puzzling, entertaining intriguing and engaging.

In *The Emotional Language of Holograms*, Paula Dawson states that the viewer experiences a sense of exclusion (2011, p.339). 'The result of the image being very spatially realistic and also behind the picture plane is to necessarily heighten the feeling of exclusion from the scene depicted' (Dawson, 2011). This exclusion resulted from frustration in some viewers, particularly because the environment that the work had been displayed in during Phase 2 emphasised the inaccessibility of the images as they were exhibited behind layers of glass in cabinets:

> '[there was a] kind of frisson of frustration and tension of inaccessibility' (Professional Artist B); '…and when I looked at the first photograph, the one that has the movement…I saw…the lips saying, "I do" and I felt a little bit of sadness. So, I'm wondering if that was intentional there, which would give another depth to it…then I would have to re-look again about this whole history' (Expert A); 'I enjoyed the works…and found myself connecting very closely with images from the past' (Viewer 22).

Enjoyment was also mentioned; two of the professional artists described the works as being magical. ‘They were magic’ (Artist A); ‘All of it is magic, lovely’ (Artist B).

6.5 Authenticity

> ‘The whole sphere of authenticity eludes technological – and of course not only technological – reproduction’ (Benjamin, 1931, p.21).

The works in this study challenge Benjamin’s concept of authenticity in relationship to technology in each phase of the work. The scientific imagery in Phase 1 was taken from a record of physical processes impacting sensors; an index of the physical impact of the light, or particles, on instrumentation; an index of the original activity which caused the trace and created the imagery. In Phase 2, the holograms contain not only the indexical nature of the analogue photograph capturing the light waves reflecting off the object onto the photographic paper, but also the holograms contain a record of the phase, or information about time, in the light wave, rather than just the wavelength, or colour, and amplitude, or brightness of the image. While the digital holograms have gone through extra processing which means the original photons have been digitised and there is no longer an indexicality with the original image, more of the original has been replicated, because movement has been captured. Holography retains the authenticity of the original because the artwork is made by hand. The hologram may also be its own work of art, montaging copied images together to create something that has never existed.

> The authentic work retains its full authority in the face of a reproduction made by hand…’ (Benjamin, 1931, p.21).

Reproductions of the family photographs have been made painstakingly; they were not mass produced.

> ‘We are compelled to find the inconspicuous place in which, in the essence of that moment which passed long ago, the future nestles still today, so eloquently that we, looking back, are able to discover it” (Benjamin, 1931b, p.67).

6.6 Unexpected results

> There was one unexpected result unearthed during the evaluation process relating to issues of accessibility. Some audience members had difficulty in seeing the artworks and perceiving the holographic artworks. This issue was the result of four different aspects: the height of the artwork; incorrect lighting angles for the viewer; the audience member's stereo-acuity issues and colour blindness; and lack of experience in seeing holograms. Audience members complained: 'I was put back a little bit by the light coming, bouncing off the back of the frame into my eyes' (Expert, 2018); '[you] have them [the lenticulars] too high and for example children…couldn't see them' (Professional Artist, 2015); 'I was lost in that room, I couldn't see anything but my own reflection' (Member of the public, 2014).

I had not previously considered that the design of the framing may have impact on the accessibility of the artwork to the viewer. One of the experts who gave feedback during the third phase, who I observed to be shorter than others, was negatively impacted by the design of the frame used in Phase 3. The frame consisted of dark mirrored surfaces at 45-degree angles. The expert had the illuminating light directed right into her eyes as she tried to view the work which was uncomfortable. However, it did bring her back to awareness of viewing and the present moment which was a hoped-for result of experiencing the work. While some audience members complimented me on the frame, its success was dependent on the individual viewer's experience and their height. The audience's physical ability to view the artworks can be negatively impacted due to the height of viewer's eyeline and their viewing angle.[31] Holograms will appear black if they are not lit at the correct angle. Another viewer who was also shorter than average quite rightly pointed out that children and wheelchair users would be unable to see the images. These issues can be mitigated for in future exhibitions.

[31] Holograms have to be lit at the same angle which they were produced and lighting angle is typically 45 degrees. Depending on the manner in which the hologram is produced. The holographic image may 'cut off' instead of seeing the holographic image one sees just a dark plate of glass if the hologram is positioned at a level which is too high or too low for a viewer. To adjust the viewing angle, viewers have to move towards or away from the hologram in order to be able to view the image, or move up and down. Traditionally moveable stools are provided by galleries and used for children so that parents don't have to pick them up to bring them up to the height of the hologram.

One person was unable to see any of the holograms exhibited in Phase 2. People with limited stereoscopic vision and colour blindness have difficulties in seeing the artwork, or a lack of experience may prevent a viewer from determining what they are seeing in a three-dimensional image if they haven't seen them before (Dawson, 2009).

The author is not the only artist to have unintentionally excluded some members of the public from viewing the artworks as a result of the way in which the artworks were shown. Mrongovius hung her work in stairwells; designed to make people feel uncomfortable as they looked at the works, intentionally making them conscious of their bodies. However, this viewing situation would have prevented people with mobility issues from seeing them. The author does not wish to limit the number of people viewing her artwork.

6.7 Summary

The 19 holograms produced in this study have been described and evaluated by three different audience groups who were able to confirm different aspects of the research question. This chapter has analysed the results of the three different phases of the research and has affirmed that the Z Axis of holographic space can contain a chronological narrative, providing an audience with a new experience with authentic, affective impact. This chapter concludes with the assertion that this study provides a new affective geometry for image display in lenticular imaging and holography; a territory that has previously been un-explored.

7 CONCLUSION

This concluding chapter summarises the information laid out in the previous chapters, restating how the research question has been answered and the contribution to knowledge demonstrated. The chapter also outlines the ways in which the research has been disseminated and may be used more widely. I include the unexpected impact of the research and recommend future work to answer questions raised by the research.

7.1 Chapter Summaries

7.1.1 Chapter One: an introduction

In the first chapter, I outlined the terminology used within this practice-based study and stated the study's contribution to knowledge. The research was to answer the question of whether temporal and spatial coherence could be achieved in lenticular imaging and holography, creating a new affective geometry and providing an audience with a new experience. The chapter introduced the structure of the dissertation, briefly describing the practice-based research methodology and explaining the context for the study, arguing for its timeliness and relevance for an international audience of display holographers. The depth of holographic space has been used to represent a chronological narrative with affective impact as a result of the research.

7.1.2 Chapter Two: a state-of-the-art review

In Chapter Two a state-of-the-art review provided a context for the research. A history of the development of photographic, lenticular and holographic media outlined how space and time have been represented and developed aesthetically and affectively, using temporal and spatial aspects both as subject matter and as a vehicle for four-dimensional image-making. The chapter ended with the assertion that despite all of the ways that had been used to represent time and space, the Z axis of holographic and lenticular images had not been used to depict an affective, chronological narrative and, as such, an opportunity to expand the media's aesthetic vocabulary existed.

7.1.3 Chapter Three: methodology – a practice-based study

The study's methodological approach was presented in the third chapter, along with a rationale for using it. The chapter included an overview of the research design; a description of the methods used in the production of the artworks; an outline of the approach taken to evaluate audience experience of the research; the ethical implications of the research; and finally the limitations of the study.

7.1.4 Chapter Four: foundation work

Chapter 4 provided the study with a background of previous work which informed the study. I outlined the impact of the work with video and photography in the 4-D Department at Exeter University during my Bachelor of Arts (Combined Honours) degree (1987-1990), and the animated holographic collages and family portraits I had produced in my Master of Arts Degree in holography at the Royal College of Art (1990-1992).

7.1.5 Chapter Five: new studies

The results section was found in Chapter Five which listed, illustrated and described the creative works produced as part of the research, along with the results of the three different evaluations that had been undertaken with three different audience groups.

7.1.6 Chapter Six: analysis

Chapter Six analysed the new studies depicted in the previous chapter and included the evaluation of audience experience of the artworks, describing themes which emerged from the qualitative data, confirming that the research question and been answered and a contribution to knowledge made. The dissertation argues that a chronological narrative can be placed within the Z axis of lenticular and holographic and space. The depth of the holographic plate in the work shown in Chapter Six, particularly in the last illustrated work, *Passing Time, Distant Memory*, contains an animated family time-line in which my ancestors recede into the depth of the hologram, and the current generation escape the

surface of the plate. The thesis claims that using the depth of holographic space in this manner to represent time can be perceived by an audience of experts which has been proven to be the case as outlined in Chapter Five, during an analysis of the discussion of the focus group of experts recorded at the City Museum of Aveiro, Portugal during the International Symposium on Display Holography 2018 at the University of Aveiro. Lastly, the thesis claimed that the artworks would provide an audience with a new authentic experience, and have an affective impact. I was able to provide evidence that an audience inexperienced in art and holography were given a new experience participating in the artwork because of their immediate responses to the work. What emerged from evaluating the experience of the audience of experts outlined in Chapter Five, Phase 3 of the study, was that the artwork brought their attention to the 'now' and that they too were part of the time-line expressed in the artwork.

7.2 Outputs and Impact

Research outputs have included 19 finished artworks, three research papers delivered at international conferences and inclusion in four exhibitions with an audience of approximately 100,000.[32] The impact for the work has included educational impact in science communication activities, and the use of animated lenticulars for science conference posters. These different aspects are described in further detail below.

7.2.1 Exhibitions

Artworks produced in the study have featured in group and solo exhibitions including: *The Royal Society Summer Science Exhibition*, London, 03/07/12-08/07/12; A *Virtual Artist* solo show at the Special Collections Gallery, University of Southampton, 26/08/14-26/09/14; *The Magic of Light* Exhibition at the State Optical Museum, Saint Petersburg Museum of Optics, 01/07/15-10/11/15, and Saltykov-Chertkov Mansion, Moscow

[32] The Royal Society Summer Science Exhibition had over 10,000 visitors, *The Virtual Artist* had almost 500 visitors, 82,000 paid to attend the *Magic of Light* Exhibition in St. Petersburg. (Audiences from 8 countries, 40 cities and more than 150 schools and colleges). More information can be found at: http://magicoflight.ifmo.ru/en/. Audience numbers for the Magic of Light exhibit in Moscow were not published.

10/02/16-29/05/16; and lastly, *Art in Holography: Light, Space & Time* at the City Museum, Aveiro, Portugal, 26/06/18-30/09/18. Audiences for the work have exceeded 100,000 people.

7.2.2 Published papers

During the course of study, I have written four papers, which were delivered at the following conferences/symposia: HoloExpo 2011 at The National Academy of Science, Belarus, (2011); the International Symposia on Display Holography (ISDH2015) at ITMO University, St. Petersburg (2015) and the University of Aveiro, Portugal in ISDH2018 (2018a and 2018b).

7.2.3 Pathways to impact

Delivering outreach and public engagement activities teaches the researcher valuable skills which contribute to the research process (Posner, 2017). Pathways to impact activities to engage the public with the research undertaken during the course of the research included holography workshops in schools and colleges, and talks to teachers and members of the public. In my capacity as the Public Engagement Leader in Physics and Astronomy at the University of Southampton I have led on two European funded research grants, *Photonics4All*[33] and *PHABLABS 4.0*, which have included making holograms with the public and with schoolchildren, and this has helped forge a link between my research in holography at De Montfort University and my job as Public Engagement Leader at the University of Southampton's Physics and Astronomy department.

The research has also been disseminated during marketing activities through the following websites, press and social media: The Department of Physics and Astronomy and my own website; as well as a variety of channels via social media, including my personal Facebook page; The Cinema4D Group; the Holography Group; Instagram; and Twitter (both my personal account and that of the Department of Physics and Astronomy). I was interviewed about my work on Minsk Breakfast TV and on the *Katie Martin Show*

[33] Information about our outreach activities in holography can be found at http://www.Photonics4All.eu and www.phablabs.eu.

BBC Solent. *The Virtual Artist* exhibit was filmed by Stephan Caspar who interviewed the author (the interview can be seen *YouTube*). *The Daily Echo* promoted the show and Jonathan Ross reported the exhibit on his Blog.

Figure 78. Minsk Morning Breakfast TV interview concerning *The Holographic World Exhibition*, Belarus Academy of Science and HoloExpo 2011. Pearl John.

7.2.4 Art/Science public engagement

The exhibition of lenticular artworks produced in Phase 1 at the Royal Society Summer Exhibition was funded by the South East Physics Network (SEPnet) who also funded the production of 4,000 lenticular postcards of the scientific data which provided the foundation of the artworks; along with an explanation of the scientific research. The postcards were disseminated for free to visitors during the first three days of the exhibition, proving very popular. My own research was communicated on a website which was advertised on the postcards. Documentation of the Royal Society Summer Science exhibition can be found at the following websites hosted both by the University of Southampton's Physics and Astronomy Unit and the author.

After exhibition at the Royal Society, the lenticular artworks were exhibited in the Department of Physics and Astronomy at the University of Southampton. A larger version

of *Nano Seconds 1: The Higgs Boson* (John 2012) was commissioned at a larger size and is on permanent display on a lightbox in a high traffic area of the Department.

7.2.4 Scientific Data Visualisation

Two lenticulars featuring diachronic data, shown below in figure 71, were featured on a poster presented at the 2017 European Conference on Lasers and Electro-Optics and European Quantum Electronics Conference. The work features research by Matteo Silva, and the lenticulars were manufactured by Mitton3D.

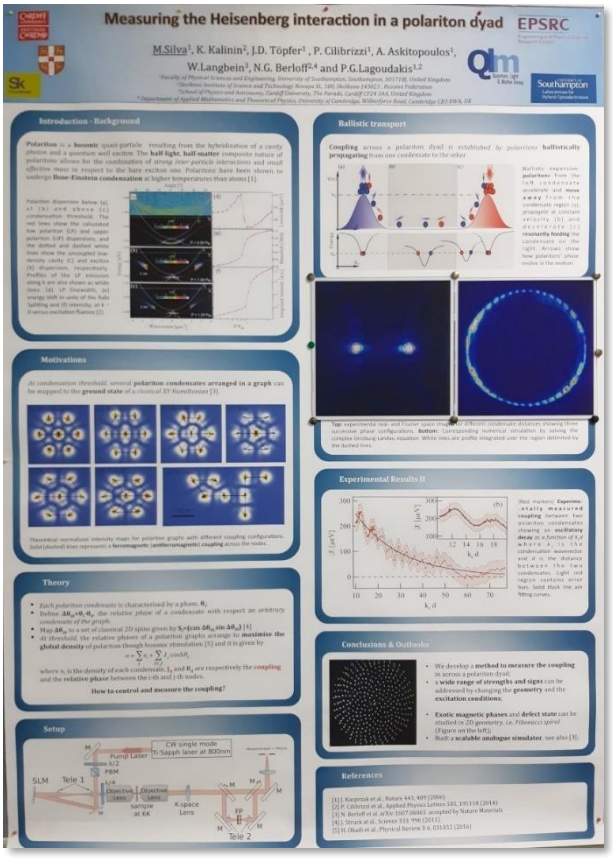


Figure 79. Scientific Conference Poster on the research of Matteo Silva incorporating two diachronic lenticular illustrations (blue circles in the ballistic transport section on the right-hand-side of the poster)

7.3 Further Development

There are four new aspects which I would like to pursue following this research: the creation of two more temporarily and spatially coherent digital animated artworks; a full colour shadowgram from colour photographs; a business creating four-dimensional

family trees utilising existing 3-D family tree software with lenticular imaging; and a journal article on the use of the silent researcher critique with qualitative data analysis for evaluation purposes as a research method for holography artwork.

7.3.1 Further artworks

As a result of work produced in this research study, I would like to produce at least three more holographic artworks; two digital works and one analogue. Digital holography is making holography more accessible; the technology has become cheaper for artists to use[34] and more easily available now that computer software can be used to create holographic images, instead of the artist having to work in a lab. However, the use of digital holography as an art medium relies on the availability of technical facilities and skilled technicians to operate them. During the course of the study one of the two main producers of digital holograms stopped production (Zebra Imaging, 2017), and recent staff changes at GEOLA threaten its on-going production of quality holographic prints. Having so few digital holography manufacturing companies requiring skilled staff with specialist expertise makes the medium vulnerable.

If digital holography is still available after the submission of this thesis, I would like to produce two further holograms utilising temporal and spatial coherence. I intend to apply technical suggestions that the experts made during the evaluation critique in Phase 3 of the research, experimenting with varying levels of transparency for animated images. I wish to overlay two family wedding videos to create moving images from two different time periods, the layers of images changing opacity when viewed at different angles. A sketch of the work is shown below in figure 72. The second artwork would utilise approximately 50 family photos and five videos to create a four-dimensional family tree.

Having recently been donated two lasers suitable for holography (blue and green diodes) I now have the option to produce true full-colour shadowgrams, similar to the monochromatic ones completed in Phase 2 and I wish to pursue this option. The full colour holography will expand my palette. Full colour shadowgrams have not yet been produced.

[34] Digital holograms can now be produced for as little as 400 Euros. (Geola.com).

Figure 80. Sketch of future digital artwork depicting two layers of overlapping video of wedding film-footage from different time periods.

7.3.2 A business

As a result of public engagement during the course of my studies, I have been asked to produce four-dimensional family trees for many others. I will explore the possibility of combining three-dimensional genealogy software with lenticular printing as a viable business.

7.3.3 Evaluation methods

The research methods I have used to evaluate audience experience will be used for future exhibitions as the process proved very valuable in my research. However, as I would argue that the most important impact of a piece of artwork is that it is remembered by its audience. I would like to determine the longer-term impact of my artworks, so will need to adjust my evaluation methods to include engaging with audiences six months after exhibition.

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APPENDIX I. Methods of production

The three different projects undertaken in this study and illustrated in Chapter Five required the use of three different technologies: lenticular imaging, analogue holography and digital animated holography. Each technology was selected for its suitability for answering particular aspects of the research question. The three different methods of production for each technology are described below.

Project One: the lenticulars

Research into temporal coherence resulted in the creation of eight large-format lenticular images. The production of the lenticulars included sketching, testing pieces and reflexive thinking, a process described in the *Concepts of Digital Media: Lenticular Imaging* guide as involving 'a blend of both conceptual creativity and technical challenges' (De Montfort University, 2016). The production involved the following practical processes: (a) selection of suitable subject matter depicting work with different time periods appropriated from different scientific research projects; (b) selection and editing of suitable diachronic data for lenticular animation; (c) the use of lenticular software to create an interlace test with print and pitch testing (d) re-selection of and editing of imagery; (e) printing and lamination of final image. These processes are described in greater detail below.

a. Subject matter:

   The selection of suitable visual material to answer the research question of whether temporal and spatial coherence could be depicted in a lenticular image was gathered as a result of discussion with scientists about the ways in which different time periods were depicted in their research work. Data was chosen which illustrated very short periods of time, measured in picoseconds and nanoseconds, to very long periods of time; measured in billions of years, or aeons.

b. Selection of data:

Visual data which changed over time and could be animated to show movement was selected from the scientific data. Eight different sets of data were chosen from the research work of eight different scientists. Each set of appropriated data set consisted of hundreds of images which needed to be edited down to just 24 frames. This number of images was due to the technical limitations of the lenticular medium; 24 frames provided the maximum movement that the medium could effectively illustrate within the parameters that were chosen. The frames were saved as JEPGS which were overlapped and manipulated in *Adobe Photoshop* C6 (KNOLL, 1988); quantitative data was removed from the images, either by cropping, cutting out or painting over the numerical information, and the size of the images was adjusted.

c. Interlacing:

The 24 layers of photoshopped images were saved as sequences and imported into the *Lenticular Construction Kit (LCK) Virtua 3D* (2007) software to produce an interlaced file. The processing of images included three different modules within the software, Virtua 3D and interlacing and calibration, and these are described below.

i. The Virtua 3D module was selected to create the parameters for the animation which included the choice of the amount of simulated depth within the Z axis of the images. Only two of the final images were four-dimensional (4-D), the rest of the images depicted two-dimensional (2-D) animations only. Once the parameters were selected, previews of the final animations were reviewed, and in some cases, images were rejected, re-edited and selected in Photoshop, and the resultant images re-imported into the *LCK Virtua 3D* software to start the interlacing process again with new imagery.

ii. The next module enabled the interlacing of the images. Vertical lenses were selected to enable horizontal animation of the images. This was considered to be a controversial decision by the manufacturers due to the resultant ‘ghosting’; an effect causing the viewer to view two different images as they move to animate the image. Unless the images are stereopairs and produce a 3-D image two

different images are viewed which means that two two-dimensional images are seen rather than a single 3D image. Despite the technical aspect of ghosting, which is illustrated below in figure 73, aesthetically the effect emphasised the diachronic nature of the data changing over time. This strengthened the image, so was retained; multiple lines are shown instead of a single line animated by the viewer.

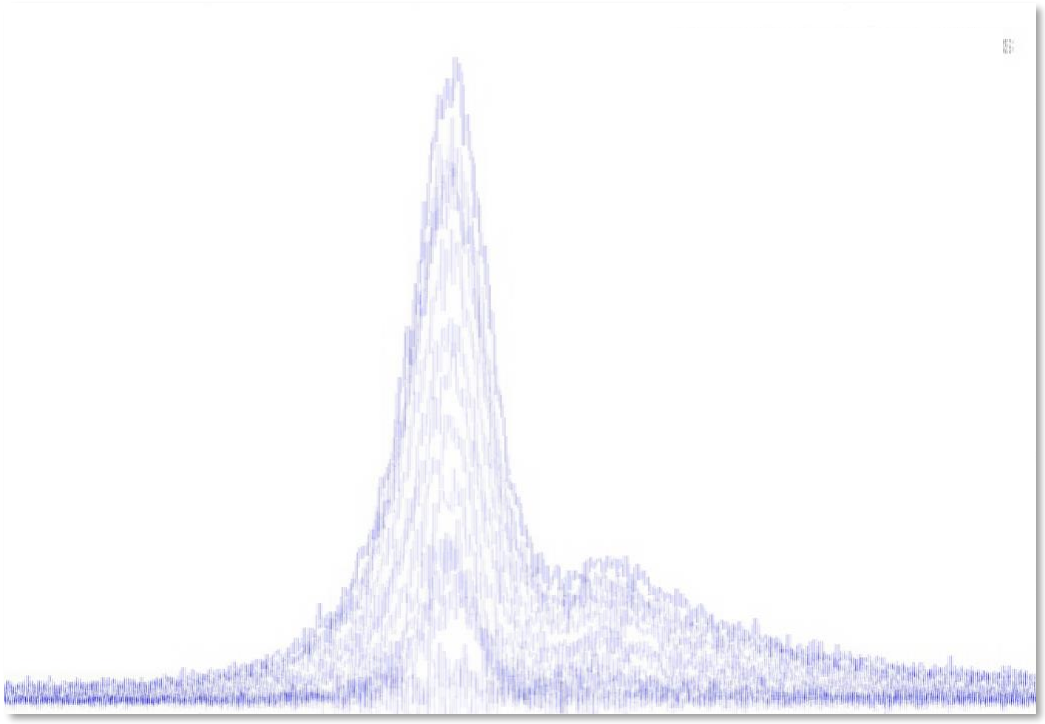

Figure 73 Ghosting effect of a vertical movement illustrated by vertical lenses

Calibration had to be done next linking the printer to the lenses; this resulted in the selection of a pitch of 29.95 lens per inch (lpi).

iii. As printing needs to be extremely accurate for the production of lenticulars, a visual test has to be made with a pitch testing chart to ensure that the lenticular image produces a 3-D image or animation, depending on the intention of the artist. The printer used was an Epson Stylus Pro 9900 and the paper was Epson Premium Gloss Photo Paper. Printing accuracy was impacted by humidity, inconsistent printing pressure, and thermal issues. The interlaced images are so small that inaccurate printing fails to ensure that the image lines up under the vertical cylindrical lenses. The calibration description is explained in full at *Creating and*

Using a Pitch Test, the manufacturer's website of the lenses used in this study. (Micro Lens Technology Inc., 2002).

d. Re-selection:

Images were either accepted or rejected at this point, and many were re-edited and the process repeated until the images were determined to be acceptable.

e. Printing and lamination:

Once the testing was over small prints of approximately 7" x 7" were printed and laminated to lenticular lens sheets, sized 30 dots per inch to emphasise animated movement, and to check proof of concept.

Figure74. Installation of *In Time* exhibit by the author at the Royal Society Summer Science Exhibition, 2014. Photograph by Simon Knight.

Figure 75. Documenting the *In Time* Exhibit in 3-D Film, Sandra Oliviera, 2012.

Large format lenticulars for exhibition were produced by printers *Mitton 3D*. The final eight artworks were exhibited at the Royal Society's Summer Science Exhibition, at Carlton House Terrace, London from 3-8 July 2012 as shown above in Figure 75. The work was documented in 3-D Film.

Project Two: the analogue holograms

This next section describes the production of ten pseudo-colour reflection shadowgrams which were made during Project Two and subsequently exhibited in *The Virtual Artist* at the University of Southampton, Special Collection Gallery in 2015. The results of the project are described on page 147. The process of creating the artworks included the following aspects: (a) the selection of suitable appropriated imagery and related objects; (b) the creation of holographic masks made from the selected images; (c) the set-up of the holographic camera; (d) the preparation of the holographic film; and (e) the exposure and development of the holograms.

a. Selecting the photographs and objects:

The rationale for the selection of photographs, text and objects used as part of Project Two was described in Section 3.1 of this dissertation.

b. Creation of holographic masks

The analogue shadowgram holograms produced in Project Two adapted processes which were first used by Benyon in 1970 in her work *Non Hologram of Hand and Hot Air*, illustrated in figure 11, page 42. Benyon used three-dimensional objects in front of a ground glass screen to produce laser transmission holographic images. This research project used two-dimensional holographic masks mounted onto a ground glass screen and back illuminated by a laser beam to create a one-step reflection hologram. The process used to create the masks involved a four-step procedure of transforming the chosen photographic and printed imagery using computer hardware and software, scanning, printing, photocopying and photographic methods. The process to create masks was adapted from that taught at the Royal College of Art[35] and is described in the table shown. Holographic film was used as the mask medium, whereas the older process utilised photographic negatives transferred to lith film, a silver-gelatine photographic film with high contrast to create the masks.

Table 6 Creating holographic masks

Step	Description of process
1.	Prints and photographs, both colour and black and white, were scanned and adapted in Adobe Photoshop C6 (ADOBE SYSTEMS,1990) to produce high-contrast black and white images.
2.	Digitised images were then inverted to create a negative image – similar to a photographic negative and achieved through using a filter in Adobe Photoshop C6.
3.	The digital negatives were printed out onto white paper with a laser printer, then photocopied onto acetate.[36]
4.	The acetates were then used as a mask placed over (discontinued) Agfa Holotest 8E75 holographic film and exposed under florescent lights in the darkroom for 10-15 seconds; the length of exposure depended on the quality or depth of contrast of the image, and the age of the holographic film. The holographic film was then developed photographically using Kodalith development processes to create a high contrast image on transparent material.

[35] The process was demonstrated by fellow student Jonathan Cope in 1992.

[36] The acetate film was not a suitable material to create a mask for a holographic image due to the birefringent nature of the material, creating unwanted optical patterns in the final image.

c. The Holographic set-up

The next process involved using the holographic masks which are described above to create the shadowgrams. A standard shadowgram camera was set up (Unterseher, 1982; Saxby, 2004) and adapted for use in the author's studio, adjusting the design for available optical table space. A red (633nm) 35mW linearly polarised *Coherent* Helium Neon Laser was used to shoot the holograms on red-sensitive Agfa Holotest 8E75 holographic film.

The research question relied on the manipulation of the Z axis of holographic space to act as a metaphor for different time periods. Adjusting the Z axis of holographic space was achieved by altering the distance between the holographic mask, which was taped to a ground glass screen, and the film sandwiched between two layers of glass. The set-up is illustrated in a diagram and photograph of the studio below.

Shadowgram holographic set-up

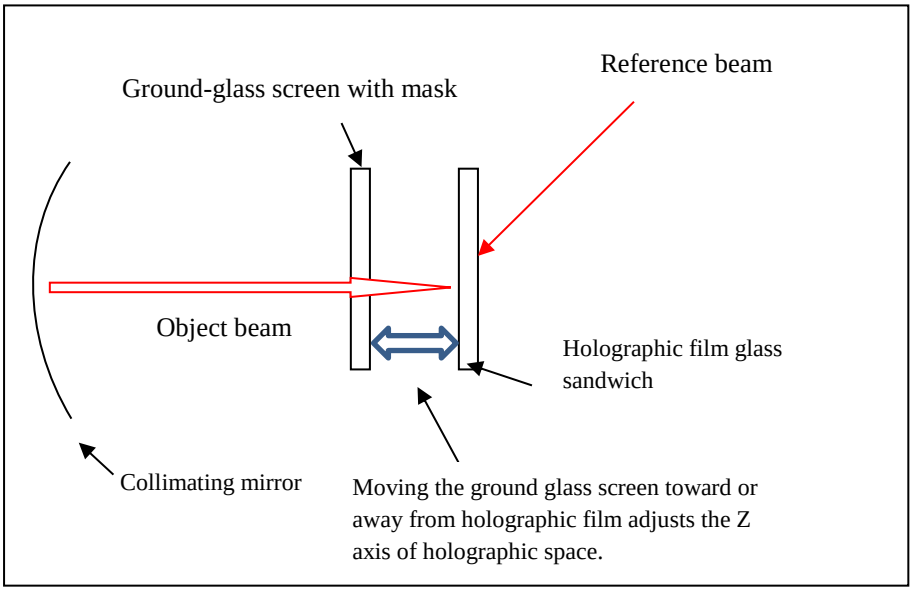

Figure 76. Holographic Camera set-up for Project Two

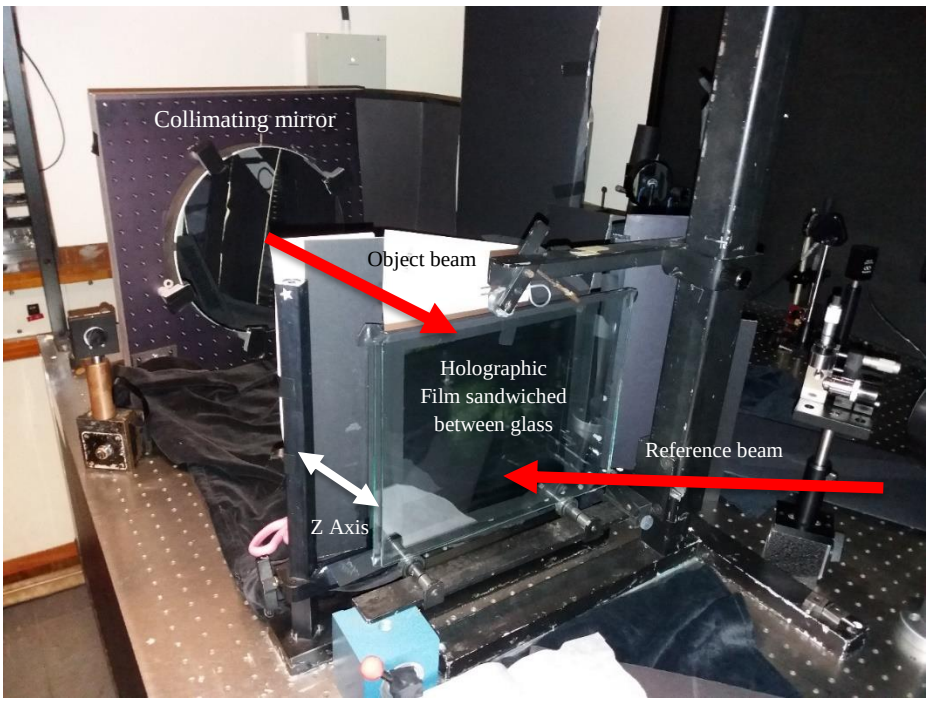

Figure 77. Holographic shadowgram set-up at the University of Southampton lab, Pearl John, 2017.

The shadowgram set up required a beam ratio power of approximately 2:1 reference beam: object beam. Exposure times lasted approximately 1 minute 19 seconds and were dependent on the density of holographic mask used. Tests were produced for each holographic image to determine correct exposure times.

d. Exposure and Developing Procedures

Each piece of holographic film was pre-swollen with triethanolamine (TEA) to colour select and to ensure the brightest results (Smith, 1984). The development process was standard for reflection holograms taught at the Royal College of Art, and used a pyrogallol-based developer with ethylenediaminetetraacetic acid (EDTA) bleach recommended by Agfa Gaevert for their film processing (Ross, 1993).

The processing left a dark stain on the film which was problematic; in order to be able to integrate the holograms with other media and objects, the film needed to be transparent. To remove the stain on the film, the holograms were rinsed in a chemical bath described in an *Applied Optics* paper entitled 'Reversal Bleaching for Low Flare Light in Holograms*'* (Lamberts, 1971) but adapted by professional holographers Ed Wesley and

Mark Diamond with the author during a *Holography Forum* discussion (2005). Three solutions were prepared in order to remove the brown stain on the holographic film from the developing and bleaching process used. The process used is described below:

Solution A

Water 750 ml

Potassium Permanganate 2.5g

Sulfuric Acid Conc. 8.0 ml

Water to make 1 Litre

Solution B

Water 750 ml

Sodium Bisulfite 10g

Water to make 1 Litre

Solution C

50g Ascorbic Acid

Water to make 1 Litre

Solution A and B were mixed using distilled water and stored in separate plastic bottles.[37]

250 ml of Solution A was measured out and poured into a 25.4 cm x 20.3cm photographic developing tray. The hologram was quickly immersed, emulsion side up, into the tray, to ensure even soaking and the tray was agitated for approximately two minutes. The film was then removed and placed into another tray of Solution B and again agitated for approximately two minutes. Once the brown stain was removed from the film, a purple stain from the Potassium Permanganate was left on the film. The film was rinsed in running water for five minutes and then the holographic film was immersed in the third bath, Solution C. After two minutes of agitation, the hologram was removed and washed in running water in the dark for twenty minutes. The final wash of the hologram was made

[37] All chemical work was done in a well-ventilated photographic darkroom, Personal protective equipment was used, and the process was followed using university safety protocols. Mixed chemistry was stored for safe disposal.

in the dark as the ascorbate solution re-activates the emulsion, making it light sensitive, and more susceptible to 'print out' (a darkening of the hologram over time). To fix the film a final wash was given in distilled water, with a couple of drops of acetic acid and wetting agent added to prevent print out and enable streak-free drying of the film.

Distilled water was used for the solution, and tap water used for washing the processed holograms. The next section describes the production of the third project.

Project Three: the digital hologram

To prepare images for the digital hologram in Project 3, *Passing Time, Distant Memory*, appropriate analogue photographic images and a video were selected from family archives; photographs from different generations were chosen which linked visually through similar subject matter and composition. The selection process was described earlier in Section 3.1. The photographs were then scanned, saved digitally as JPEGS and manipulated to increase contrast using *Adobe Photoshop* (Knoll, 1988). One of the photographs was flipped horizontally to ensure that all the images mirrored one another in terms of composition. The animated image in the artwork was transferred from video, to DVD, then edited in *Adobe Premier Pro*, (Adobe Systems, 2003) shown below in figure 78, to select seven seconds of film, and exported to QuickTime (Apple Inc., 1991) to enable it to be imported into *Cinema 4D* (C4D) (Maxon, 1990).

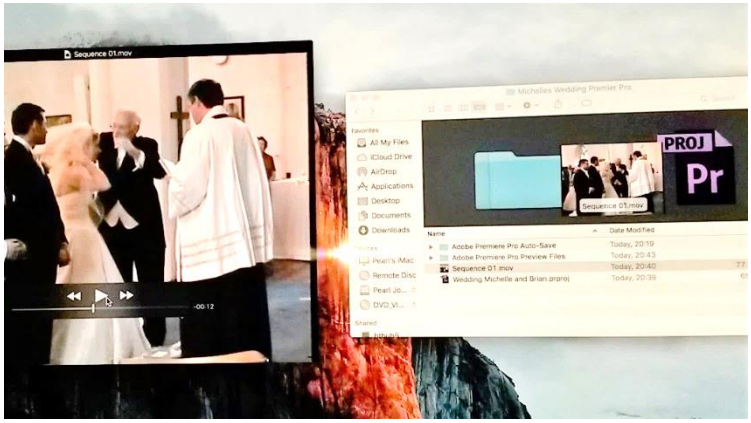

Figure 78. Film transferred from video to DVD edited for content in *Premier Pro*, Pearl John, 2018.

In the C4D software, the photographs and video clip were converted to use as textures on flat planes which were placed both in front of and behind the image plane of the hologram and the images were resized and composed. The planes were tilted in different directions and three different light sources were added to emphasise a three-dimensional element of shadowing to the subtly three-dimensional, animated scene as shown below in figure 79.

Correct parameters required for the virtual cameras which determined the size of the final hologram and the number of frames needed to produce the 4-D image were provided by GEOLA. The GEOLA parameters calculated for data preparation are described in detail in *Ultra-realistic imaging: Advanced Techniques in Analogue and Digital Colour Holography* (Bjelkhagen, 2011, p.348).[38] After rendering, the 2,002 JPEG images, were transferred to GEOLA for printing.

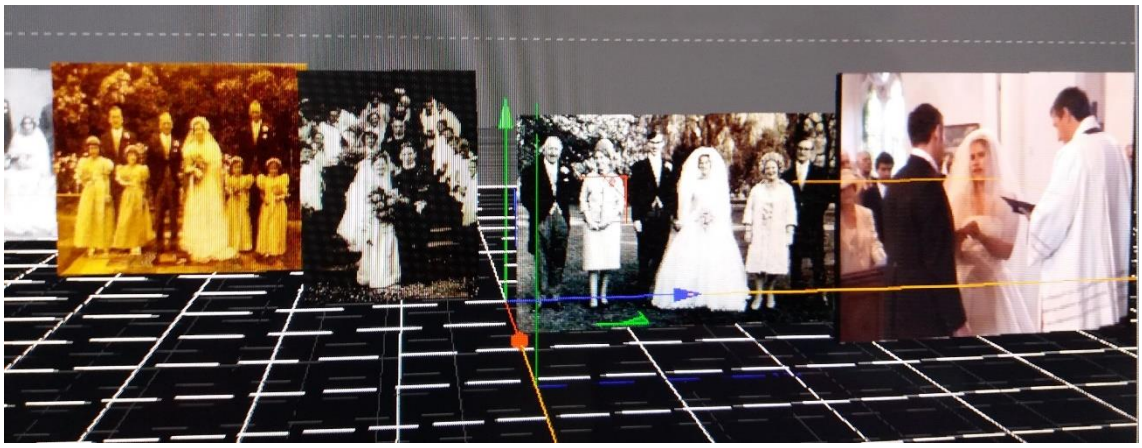

Figure 79. Images being prepared in Cinema 4D for *Passing Time, Distant Memory* iLumogram, Pearl John, 2018.

The digital printing process used was a horizontal-parallax-only (HPO) animated hologram, described as an 'iLumogram' by GEOLA. This process included exposure of panchromatic holographic film by three pulsed lasers to target individual hogels, or holographic pixels. After exposure to the pulsed laser light film was developed to produce the final 25cm x 60cm artwork.

[38] Instructions were written for *3D Studio Max* (Autodesk, 1996) and needed further clarification for use with *Cinema 4D.* Dietmar Öhlmann owner of Syn4D, artist, holography consultant, and former colleague from the Royal College of Art, provided the correct parameters for the software.

APPENDIX II: Technical Terms

Analogue holography	Holograms made with lasers.
Animated holography	Holograms containing multiple images which change depending on the replay angle. Holograms which move include; cylindrical holograms, integral holograms, stereograms, multiplex holograms, iLumograms (GEOLA)
Coherence	Properties of a light wave: light waves of a single frequency are in phase.
Digital holography	Holograms produced from computer software. Up to 900,000 individual images can be combined to produced 3-D animated images in full colour.
H1 and H2	The master and transfer hologram. Copying a H1 hologram with an H2 transfer hologram enables the artist to have full control of the Z axis of holographic space and whether the final image recedes into virtual space, or projects into real space.
Hogels	Holographic pixels in digital technologies
Holographic space	Holographic space consists of the virtual space behind the image plane of the hologram; the real space between the image plane and the viewer; and the image plan itself.
Interference	Interference is the result of overlapping coherent light waves. When waves of laser light are in phase and overlap, the height, or amplitude of the wave increases, creating a bright point of light, and when the waves of light are out of phase, the waves cancel each other out and a dark area is observed. Holography records interference patterns. Where bright points of light hit a light sensitive holographic plate the structure of the plate is altered, which impacts the way that the light is shaped when the developed holographic plate is lit.
Laser	Light Amplification by Stimulated Emission of Radiation. A coherent light source required for holography.
Laser transmission hologram	A hologram only viewable in laser light.
Lenticular imaging	Also known as a microlens work. A 3-D or animated image produced from interlaced images covered with lenses
Multiplex hologram	A white light reflection or transmission animated hologram produced from a series of photographs or film stills.
Pseudoscopic	An image turned back-to-front spatially.
Reflection hologram	A hologram which is usually monochromatic and illuminated from in front.
Shadowgram	A holographic silhouette of the object being copied.
Spatial Coherence	The ability of a beam of light to remain in phase across the width of its beam.
Stereogram	A white light reflection or transmission animated hologram produced from a series of photographs or film stills.
temporal incoherence	Either a scientific term to describe how monochromatic a source is, or a creative term to describe an image in which the narration does not make sense as the viewer looks at it from right to left and left to right. The temporally incoherent image also suffers from time smear and doubling (Desbiens, 2009)
White light Transmission hologram	Invented in 1969 by Stephen Benton at MIT, the holograms are made with a slit blocking the object beam during the H2 exposure which results in holograms with thin bands of spectral colour. As a result, the hologram is also known as a 'rainbow hologram' and mirror-backed versions are used widely for security purposes and for marketing labels.