Embedded 3D Web Based Content for the Creation of an Interactive Medical Browser

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i. Abstract

The research project set out to examine the possibility of presenting 3D medical visualisations through a web browser to help suffers and their families understand their conditions. Explaining complex medical subjects and communicating them simply and clearly to non-specialists is a continuing problem in modern medical practice.

The study set out to complement current methods of health communication via pamphlets, posters, books, magazines, 2D & 3D animations and text based websites as all of these have disadvantages which an interactive 3D system might be able to overcome.

The reason a Web Browser approach was adopted was due to the wide availability of browsers for a large number of users. Additionally modern web based 3D content delivery methods negate the need to continually download and install additional software, at the same time allowing for a high quality user experience associated with traditional 3D interactive software.

To help answer the research questions, a prototype artefact focused on Asthma was produced which was then tested and validated through user testing with a small group of Asthma suffers and evaluated by medical professionals.

The study concluded that effective communication of medical information to sufferers and their families using 3D browser based systems is possible and can form a useful part of a medical communication system for non-specialists.

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i. Notes to Help Review the Artefact

The artefact is a medical simulation tool based on asthma and works through a web browser.

Artefact can be found on the following hyperlink, please use the Firefox web browser:
www.medical.mudboxcentral.com/?page_id=2

Youtube video of artefact can be found at the following hyperlink:
www.youtube.com/watch?v=3lwdmOYGsj8

Standalone asthma medical simulation, unzip and double click (WebPlayer.unity3d)
https://app.box.com/s/3e3g4noh11b4sus69yza

1.0 Introduction

When people get ill they need information about complex technical subjects to be communicated to them simply and clearly. This study looks at one way in which this can be done. It set out to see if the technical advances in 3D web browser technology could be an effective tool for communicating medical information.

This study will allow for more research into the platforms of web browser technologies and give a general overview of the real time graphics medical market. A prototype has been created to allow user testing to help support the researcher's claim that a 3D medical browser could prove useful as a medical informatics tool.

Three-dimensional graphics that work through a web browser have dramatically improved in recent years, yet they are still not in common use, especially in the medical context. Callum Welsh is an Art Director at Random 42, a medical visualisation company with twenty years history in winning multiple 3D medical animation awards, (Random 42, n.d.). Callum suggests real time graphics in the near future may replace rendering medical animations altogether and that there is a huge potential market for Web Based Real Time Visualisation (Welsh, 2013).

This study aimed to create a proof of concept of a Web Based 3D medical simulation that uses games engine technology as a cheap solution for 3D interactive software, and that bypasses the traditional download and install scenario.

Looking inside a 3D simulated human body might help sufferers and their families relate to the damaging health-related effects of many issues including obesity, heart disease, cancer, heavy drinking, AIDS/HIV, smoking and poor life style choices.

Games Engines such as 'Unity' and 'Unreal 4' have released new authoring tools for embedded web-browser technology which allow users to view 3D content on the internet. The graphics fidelity is now at a stage where it could be used to explain illnesses and treatments to patients and their careers, or in a more general context by the public to help aid their understanding of medical vernacular through an interactive and exploratory method. This study aims to provide new learning tools to help communicate with patients and their family about medical conditions. The ambition is to create a prototype that could complement the current methods of health communication via transdisciplinary strategies, both in the United Kingdom and internationally as well.

1.1 Rationale

The researcher wanted to provide an information tool to complement current health communication such as pamphlets, posters, books, magazines, and other forms of health communication dissemination. According to asthma UK a leading asthma charity organisation,

> "There are 5.4 million people with asthma in the UK, The NHS spends around £1 billion a year treating and caring for people with asthma, There were 1,167 deaths from asthma in the UK in 2011, An estimated 75% of hospital admissions for asthma are avoidable and as many as 90% of the deaths from asthma are preventable" (Asthma UK 2015).

Under thirty four year olds spend more time online than other age groups and half of that demographic is under twenty four, it is my ambition to target that audience, (see table Fig. 1 for statistics).

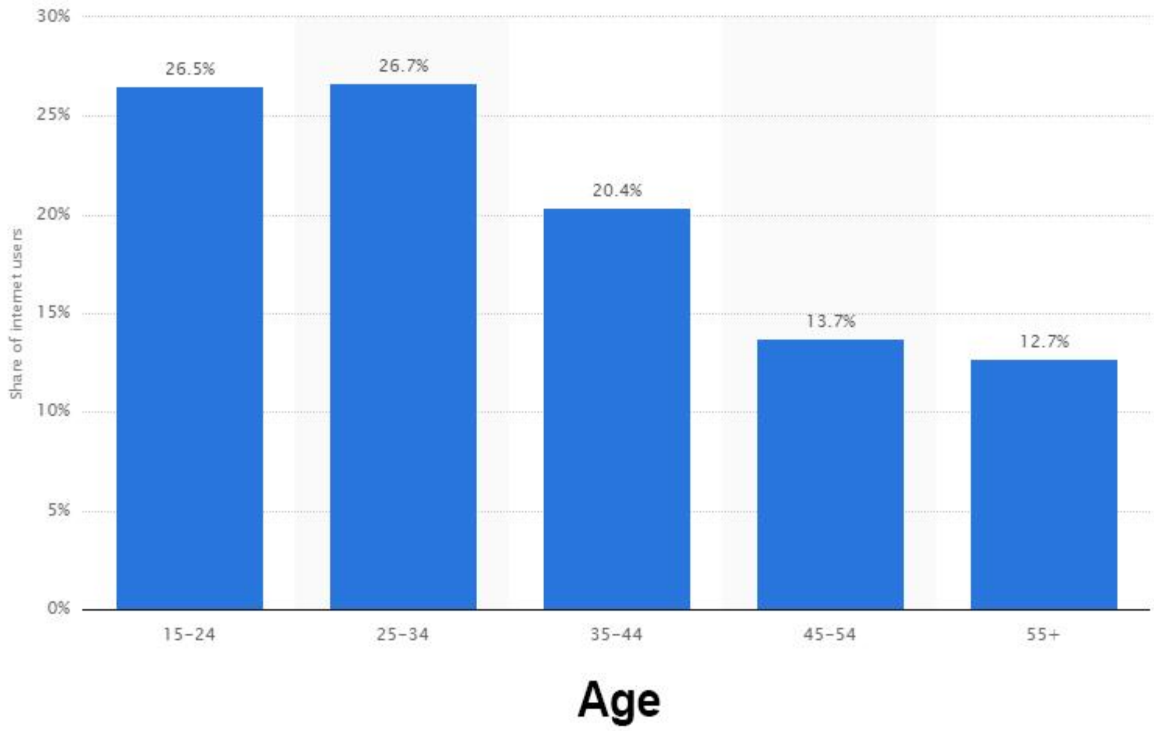

Fig. 1 *Statista, Distribution of internet users worldwide as of November 2014, by age group* (2014) statista.com

As a proof of concept the researcher focused on explaining one medical ailment. The tool had to give an accurate and coherent account of the processes and symptoms of a condition. The product was designed for patients and their families rather than medical specialists.

Asthma is the chosen ailment due to the researcher growing up seeing a sister suffer from the disease. A personal observation of how quickly the condition can attack and how frightening it can be for the suffer and family members, especially when the condition is severe and life threatening and needs hospital treatment all factored into the choice of the medical condition.

The researcher wanted to use “Real Time 3D Graphics” for creating an artifact that explains the condition and triggers of asthma. This would be done by moving a digital camera inside the body to show the lungs and then onto the airways. This would explain how the airway walls swell, the muscles around the airways contract and mucus builds up which causes the symptoms of wheezing and coughing.

The objective in creating a working prototype that works natively in web-browser (rather than downloadable software that's fixed to one particular platform) will prove that a system of health communication can be built cheaply, effectively and work instantly internationally from a website anywhere in the world on most midrange PC and Apple platforms. There will also be a downloadable executable version with graphics option settings to help tailor the experience based on the user's graphics card power.

Medical informatics help the public with many miscomprehensions in their understanding of medical conditions, which directly affect health compliance and life style choices, according to Ortiz;

> "Studies have shown that patients who understand their conditions and are involved with their doctors in making health care decisions are better able to deal with their illnesses. However, patients often do not have access to accurate and reliable information or are not able to retrieve, understand, and use this information to meet their individual needs." (Kass-Bartelmes & Ortiz, 2002)

This suggests there is a need for clear, accurate and "easily accessible" information that can be used in the medical context to help explain medical informatics for the general public.

The areas for the artefacts expansion would be to build more simulations to target ailments like heart attacks diseases, strokes, cancers, as they are all by far the biggest killers in today's society according to the World Health Organization (WHO, n.d.). And according to Wright "One-half all deaths in the U.S. can be attributed to preventable or behavioral and social factors" (Wright et al. 2007:5) and according to the Centre for Disease Control and Prevention, "In America alone 2.43 million people die per year" (CDC, n.d.). This means 1.2 million people die in America per year from preventable or behavioral and social factors.

Another factor is the cost to society to care for these people, for example obesity costs the NHS £5 billion per year (The Department of Health, 2011). To help with health compliance a possible method could be a health communication tool that consists of the damaging effects of obesity in a 3D simulation. The visceral fat could animate in growth to show the damaging affect it has around organs. A health communication tool of this kind, could be used to complement pamphlets, posters, books, magazines, and many other forms of health communication.

The message from UK government and medical professionals for healthier life styles to the general public has many issues and needs to be improved, according to Wright;

> "A wide variety of problems still exist in terms of our nation's ability to provide adequate care for everyone and in terms of maximizing its efforts to prevent and control diseases and other health problems. It appears that some of the severity of many of these problems could potentially be lessened by improving communication among providers, between providers and patients, between health researcher's, and between public health leaders and the public" (Wright et al. 2007:4)

National health compliance is traditionally influenced by medical professionals explaining or advising the general public with the aid of sources such as books, publications or magazines. According to Eysenbach;

> "Until recently medical informatics focused on developing applications for health professionals: medical informaticians looked at medical practice mainly through the eyes of health professionals rather than through the eyes of patients" (Eysenbach 2000: 5,6).

And with 1.2 million deaths (in the US only) due to preventable or behavioral and social factors there might be an area that 3D real time simulation software can help complement current practices.

This study will allow for more information to be gathered on the topic in health informatics which is growing in popularity, Greenes and Shortliffe wrote;

> "After many years of development of information systems to support the infrastructure of medicine, greater focus on the needs of physicians and other health care managers and professionals is occurring to support education, decision making, communication, and many other aspects of professional activity." Greenes and Shortliffe (1990:1)

1.1.1 Research Questions

The research questions that underlie this thesis are from the point of view of 3D medical informatics and how to best support the general public with medical vernacular.

1. How may one produce a 3D medical visualization system that works through a web browser?

2. How may any such system communicate effectively to a target audience using a 3D medical simulation that works through a web browser?

3. To what extent is the artefact an accurate description of asthma triggers and their symptoms?

4. What are the learning outcomes taken from user testing the prototype on asthma sufferers and medical professionals?

1.2 Measures of Success

This thesis contains a working medical simulation prototype as part of the research; it focuses on explaining the respiratory disease of asthma. This will allow a target audience of asthma sufferers to user test the artefact and test if it can communicate effectively. Medical Professionals will also user test the artefact to validate its accuracy and description of asthma triggers and their symptoms. Feedback through a Likert scale, comments and resonances from both sufferers and professionals will be analyzed and help draw a conclusion and see if the artefact is a success.

1.3 Chapter Summary

This chapter set out to explain the reasoning to the study. It explains how a 3D medical health information tool embedded into a website could complement current health communication tools. It explains that the researcher will build a prototype tool that will work instantly internationally from any website anywhere in the world.

The study suggests there is a need for clear, accurate and easily accessible information that can be used to help explain medical informatics to the general public. It explains that millions of people die every year due to preventable or behavioral and social factors. If the artefact is broadly a success it will headlight that a 3D web browser could communicate to the public about diseases, health problems and health compliance and be improved.

The research questions are set out to be explored through the creation of the artifact, user testing and analysis of the data to help draw up answers, conclusions and limitations to the study.

The next chapter reviews work related to the field of medical health informatics and web browser technology.

2.0 Literature Review

The approach set out in this Literature Review was to start with an explanation of medical visualization; this gives the study some context and explains the pedagogy of the subject matter. The study then covers the current medical information systems with a focus on 3D interactive systems.

A subcategory of Games Development know as Serious Games is explored focusing on Medical Informatic examples; conferences such as ‘The Games for Health Project’, which present best approaches to improve health and healthcare from a provider and patient perspective are also explored (The Games for Health Project, n.d.).

Software Development Methodologies have been investigated to help with breaking down the creation process of the 3D Medical Browser. Finally a review of Survey Methodologies to help support the Software Evaluation makes up the latter part of this Literature review.

2.1 A Brief Overview to the History of Medical Visualization

Medical Visualization is designed to visually convey information that comes from the work of scientists, anatomist and artists in collaboration with one another (Loudon, 2001: 3). There is an expectation that medical illustrations will be accurate but there is also recognition that any illustration cannot be a substitute for the a real human body, according to Loudon;

> “The body was the book, which was to be read. Even Vesalius, who in 1543 effectively established illustration at the heart of anatomical learning, reminded his readers that pictures were not a substitute for the real thing” ” (Loudon, 2001: 3).

The Renaissance saw the rise of many notable anatomists such as Albrecht Dürer (1471-1528), Andreas Vesalius (1514-1564), Bartolomeo Eustachi (1514 -1574) and Giulio Casserio (1552-1616). These men were anatomists, experts in the Latin terminology of anatomy and in locating human body parts.

Leonardo Da Vinci's (1452-1519) drew the bodies himself but was not published while he was alive, it was not until 1651 that Leonardo's work saw its first publication, 135 years after his death. Clayton and Philo (2010: 28)

Also according to Clayton in a video interview;

> "Throughout his career Leonardo intended to publish his anatomical research as an illustrated treaties on human anatomy, Leonardo should and could have been one of the great figures in the history of anatomy but is essentially just a footnote" (Leonardo: Anatomist - by Nature Video, 2012).

The notable anatomists 'Dürer, Vesalius, Bartolomeo and Casserio' collaborated with the most outstanding artists they could find to produce accurate representation of anatomy for print. According to Loechel;

> "During the Renaissance art in general was a mixture of realism and idealism and medical illustration was no exception. The physician or anatomist of this period had a titanic job on his hands to find an accomplished artist who would undertake to work on cadavers". (Loechel, 1960:169)

A book that shows illustration in an interactive manor was produced by Johann Remmelin's, 'Catoptrum Microcosmicum', it was printed in 1619. Remmelin's book remained in publication until 1754. According to the Hardin Library for the Health Sciences "Catoptrum Microcosmicum, probably the most extensive anatomical "flap book" ever produced." (Hardin Library for the Health Sciences, n.d.)

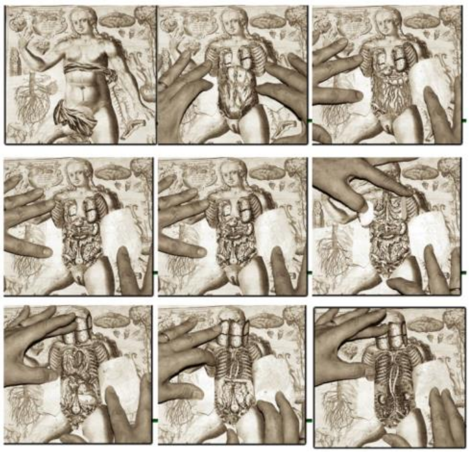

Fig. 2, *Catoptrum Microcosmicum, Iowa Digital Library*, (2013) digital.lib.uiowa.edu

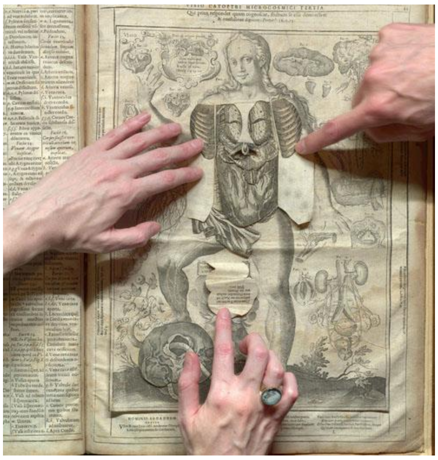

Fig. 3 *Catoptrum Microcosmicum*, *Iowa Digital Library*, (2013) digital.lib.uiowa.edu

Remmelin's work is very extensive in terms of intricate anatomical details. The page in figure 3, has a series of flaps opening up to reveal the various layers to the human body and its organs. On the page there are different sorts of information, images, physically constructed structures with connections between the different organs that are articulated not just by the print but the physical relationships on the page between the flaps and there is also text to help further explain illustrations.

The production costs to produce a book with interactive flaps is obviously more expensive to produce then a flat image, this could have been driven from a sense of dissatisfaction of a flat 2D image which is a common theme right up to the current day and why we have so many different forms of medical visualization. What Remmelin's book allows the user to do is refer to the text to learn about a particular organ and then move on to the next section and go back and recap about a previous body part.

Medical illustration has a long history of abstraction of the human form and moving away from a photographic realism towards a schematic realism which is in fact more effective in communicating the internal workings of the human form. Two important people to note in regards to simplifying anatomical details in the visual representation of medical imaging are Henry Gray and Henry Vandyke Carter with their first publication of Greys Anatomy in 1858 (Richardson, 2009: 5). According to Richardson;

> “Gray’s anatomy is probably the best known medical textbook in the world. So highly regarded is Mr. Gray’s book that it has been placed alongside the bible and Shakespeare as fundamental to the education of a doctor”, (Richardson, 2009 8: 5).

Richardson talks about the simplicity of reading and using Gray’s Anatomy;

> “The eye could grasp what it needed at once. The anatomical names appearing directly on the appropriate structures meant that there would be none of those nasty little digits dotted all over like numerical smallpox. Furthermore, there would be no need for footnotes to explain everything”. (Richardson, 2009: 114)

Figure 5, illustrates Richardson’s point about digits being dotted all over like numerical smallpox.

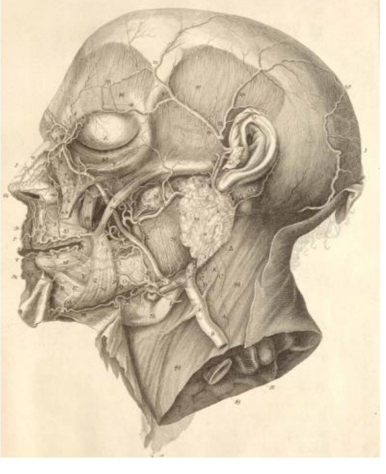

Fig. 4 *Artist - C.J. Rollinus “Gottingen-Copperplate Engraving, von Haller. A”* (1756) (2013) nlm.nih.gov

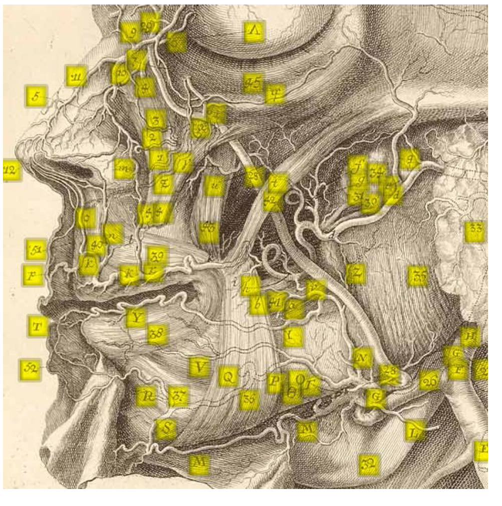

Fig. 5 *Artist - C.J. Rollinus “Gottingen-Copperplate Engraving, von Haller. A”* (1756) (2013) nlm.nih.gov

When ‘Gray’s Anatomy’ was first published 1858, the name tags where placed straight onto the body parts, as can be seen in the figure 7.

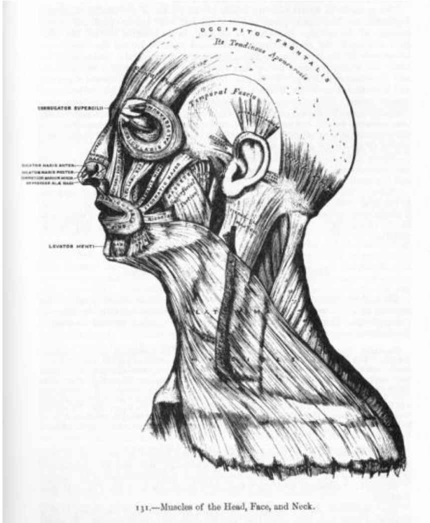

Fig. 6, *Artist - Gérard de Lairesse, anatomist - Govard Bidloo "Ontleding des menschelyken lichaams"* (1690) (2013) nlm.nih.gov

Fig. 7, Artist - Henry Carter, *Anatomy of the Head* (1858)

Gérard de Lairesse illustration is very detailed and realistic in terms of the small details and looks like it has been drawn from life, while Carter introduces a different from of illustration, the approach makes it much easier to understand the names of the muscle anatomy.

To provide another comparison to Henry Carter in Figure 9, the researcher has placed an example from Jones Quain, Figure 8,. The styles are very different, they are only seven years apart but Quain holds onto older illustration traditions.

Fig. 8 Artist - Jones Quain, The Uterus (2009)

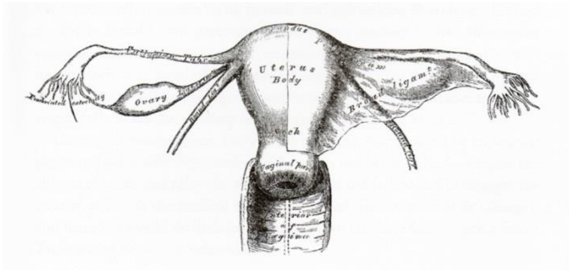

Fig. 9 Artist - Henry Carter, The Uterus (2009)

Quain’s illustration is a realistic depiction of the Uterus, it could have been detached from a dead woman’s womb. The flesh hangs down to show the effects of gravity. The pins indicate that the organ has been nailed to a board. According to (Richardson, 2009: 227) “Carter's image is a diagram of the life giving womb, it does not-as in Quain's case- convey the impression that a woman has died for us to see it.” (Richardson, 2009: 227).
Another notable Artist and Physician that had a wide spread of communication in medical information and interactivity in the form of thirteen books, four thousand illustrations and over two hundred pamphlets was Frank Netter (Dominiczak 2012:1).
According to Dominiczak “The Books could be found in medical libraries across the world, and they stood out from conventional texts.”, “There was, however, a medical illustrator whose style of presentation became as important to his readers as the scientific message. His name was Dr. Frank Netter (1906–1991)”. (Dominiczak 2012:1).

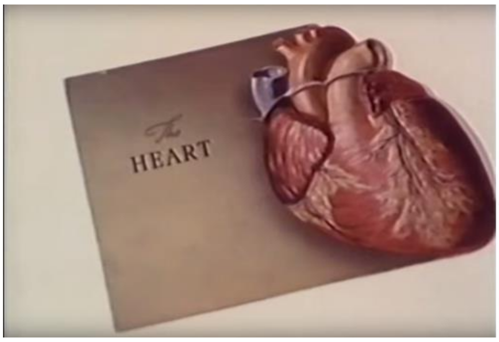

Fig. 10, Fig. 11 *The Netter Collection of Medical Illustrations* (2010) (2015) youtube.com

In figure 10 and 11, the illustrations have an element of interaction as the user opens the pamphlet to reveal a cross section of the heart that reveals the inner workings of the heart muscle which is accompanied with some text to explain the muscles function. Like Remmelin's flap book “Catoptrum Microcosmicum”, Frank Netter is pushing 2D interaction in form of a pamphlet.

As well books, medical journals and pamphlets, Frank Netters work also comes in different forms of media such as an Interactive CD-Rom ‘Interactive Atlas of Human Anatomy’ (1998) and the ‘Netter's Anatomy Atlas App (2012)’ which can be found as an ‘iPad App’ and can be downloaded from the iTunes store to work on Phones and Tablets. According to the description in the iTunes store the software comes with lots functions including muscle information, innervations, actions, blood supply and label quizzes.

The CD-Rom, IPad and other forms of Tablets can allow for interactive forms of health communication to become learning tools. An example is ‘Introduction to health Care in a Flash! An Interactive, Flash-Card Approach’, Turner. Marilyn (2014). This helps many learners as the information is visual, audio and requires some engagement due to the interactivity. According to Turner;

> “Many people are auditory learners. In order to grasp new information these people need to hear it spoken. The more complex the information, the more they need to hear it” (Turner 2014: xxviii).

What the digital tools provide is to help build on the core knowledge base that has already been established. According to Loudon;

> “Every era and culture that has produced visual images concerned with the human condition in a social context has generated what may be called medical art. If we attempt to define what we mean by medical art, it is difficult to know where to draw the boundaries. Any image which is made to perform some kind of role in how we perceive our bodies and alter our state of health can potentially be included” (Loudon, 2001: 1).

Medical visualization is a living tradition, by using 3D digital media does not change the traditions that where established in pre digital media. Part of the effect of the rapid changes in technology and the availability of technology are that the nature of medical illustrations change and adapt to make use of emerging technologies.

2.2 Current Medical Information Systems

The public can obtain health information from a very varied range of sources, some are authoritative and some are not but there are ways of searching for authoritative sources which is discussed in this chapter. According to Wright;

> “The area of health communication continues to grow and diversify. New areas of research have expanded health communication into health domains that many people in the communication discipline probably did not consider 30 years ago” (Wright, 2012: 7)

There are many ways patients and their families find information to self-educate themselves about medical conditions. According to the Cutilli;

> “Individuals use other sources of health information (e.g., TV, radio, newspaper, magazines, Internet, and family/friends/coworkers) to supplement information provided by healthcare professionals.” (Cutilli, 2010: 1).

To expand on Cutilli’s comment, in the UK pamphlets are common place in waiting areas in hospitals, private clinics, health related charity organisations and inside doctors surgeries which are generally a good authoritative source of information.

Internet websites such as the World Health Organisation and the National Health Organisation (NHS) are very large resources for gaining knowledge on a range of medical ailments. The NHS has a certification scheme called the “The Information Standard” to promote their information as an authoritative source, According to the NHS website;

> “The Information Standard is a certification scheme for health and social care information. It has been established by the Department of Health to help patients and the public make informed choices about their lifestyle, their condition and their options for treatment and care” (NHS Information Standard, 2014).

The NHS website connects the public to other organisations that are associated with medical conditions such as “Asthma UK”. The public can then obtain more information through these bodies. Forums are part of these resources where the public can obtain mutual support and broaden their topic search which is another form of health information-seeking behaviors by patients.

2.3 Digital Information Systems

The NHS website has a section on the front page called ‘Health A-Z’ (NHS Choices, 2012) where there are various search functionalities to help focus on an area of the body associated with a medical ailment. It is an authoritative and informative source of information on a range of ailments that contains still images and videos.

In the *“NHS Choices”* website as can be seen in figure 12 the male has his organs showing in his chest, this happened by the researcher rolling a mouse over that particular area. By clicking on the organs, another image appears that shows the anatomical image approximately twice the size as if zoomed into the chosen area. At the same time the relevant medical conditions correlating to that area of the body appear. Then when you click on a chosen medical ailment a new page appears, (see figure 12).

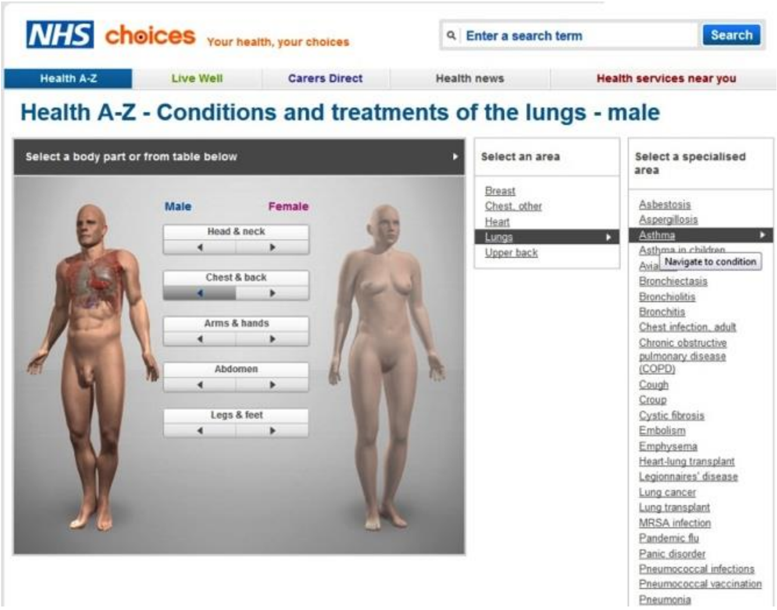

Fig. 12 *"NHS Choices"* (2014) nhs.uk

Fig. 13 *"NHS Choices"* (2014) nhs.uk

In figure 13, the website explains the condition asthma. There was a small window with a rendered animation that has very clear narration about the medical condition. There are tabs at the top of the page that present a range of information data such as 'clinical trials', a comprehensive ‘list of medicines’ that are available for the condition, in this case asthma and ‘the map of medicine’. According the NHS website;

> “The Map of Medicine is used by doctors throughout the NHS to determine the best treatment options for their patients. NHS Choices offers everyone in the United Kingdom exclusive and free access to this cutting-edge internet resource, which lets you see exactly what your doctor sees” (NHS about choices, n.d.).

The information in the ‘the map of medicine’ has been approved by the UK's leading clinical experts and was based on the best available clinical evidence there was to date. The researcher contacted the NHS Information Policy Team and asked if it would be possible to use information from their website in order to create a 3D medical browser. The NHS policy email gave permission for the researcher to re-use information free of charge in any format or medium from the NHS website for the project, see appendix for a copy of the email.

2.4 Interactivity and Medical Representation

A company that specializes in medical apps was ‘3D4Medical’ (3D4Medical, n.d.). They have apps that work on many platforms such the iPad, iPhone, Mac OS, Android and Windows. The ‘3D4Medical’ website has four libraries of content under the heading ‘Body Systems, Body Regions, Health & Fitness and Patient Education’ and each can be purchased between two to ten dollars. The app had many interesting features such as anatomical relationships between the bones are explained. The user can select multiple objects such as bones and isolate them for further investigation. The text was hard to see which might be an issue of the product working on an iPhone rather than a tablet. The product was an anatomy browser and there is not much that describes medical ailments apart from a dental section.

A company called ‘Blausen Medical Communications’ (Blausen, n.d.) has lots of medical animations on their website. According to the website they are “an internationally recognised leader in medical and scientific animation and illustration. Our award-winning work combines stunning visual drama with unwavering scientific accuracy. It is reviewed continuously by a team of industry experts and our Medical Advisory Board”. Founded in 1991 they are celebrating their twenty third anniversary,” (Blausen, n.d.)

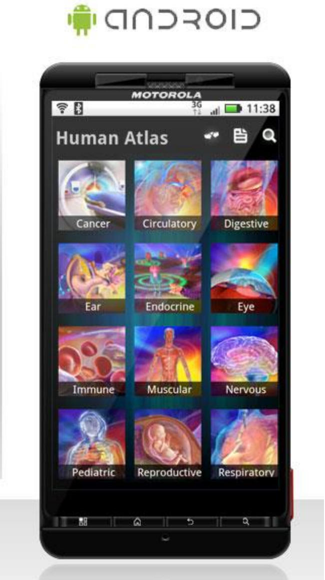

Fig. 14, *Blausen* (n.d.)

blausen.com

The researcher downloaded the Medical Communications browser on a smartphone and on an iPad, as can be seen in figure 14. The software has around 10 animated cinematics but the vast majority is static rendered images with text based answers to medical conditions. For further content the user has to purchase individual animations for each ailment. The animations reviewed were clear and proved to be a good learning tool to learn the basics of medical understanding of a particular ailment.

The website has an awards section in which it showcases the numerous awards it has won since 2003. The list of competition prizes is extensive: “eHealthcare Leadership Award, Web Health Award, INDEX Award 2011 Nominee, Innovations in Healthcare Competition” and many more (Blausen, n.d.). The company has tailored their 3D animations into different media devices and you can watch them on Tablets, Smartphones, Web Application and Bedside Units and on the Internet via PC and Apple computers.

Art Director, Callum Welsh from ‘Random 42’ (Random 42, n.d.) is a medical animation company, responded to a question from the researcher via an email about real time medical visualisation he states it is going to be a huge growth area once the next generation of engines are on the market.

> "The next generation of real time graphics technology such as UE4 and Unity 5 is going to see huge improvements in real time graphics and may even replace rendering medical animations altogether as the demand for real time visualization will grow and clients will expect to see both a finished animation and an interactive demonstration. Currently there is a huge gap in the market for Tablet and web based visualization" (Welsh, 2013).

Where Welsh mentions real time graphics may soon replace rendered animations, this is a point shared in an article by 'Creativebloq' titled "Artists and TDs are turning to real-time engines to speed up the process of content generation" Jarratt. S (2015). Also in the article, executive producer Duncan Burbridge from 'The Third Floor' who are a visual effects company specializing in pre visualization for the film industry , "In a desire to improve its offering, the studio is currently evaluating Unreal Engine 4.5 as a replacement, I think the output speaks for itself" Jarratt. S (2015). The 'Unreal Engine 4.5' that Burbridge mentions will be released in 2014, and it will allow games programming and graphics capability to be improved to help deliver content to the current generation of games consoles. This is particularly useful for training simulations as environments will have much higher-fidelity.

2.5 Interactivity and Simulation Software

Some of the largest games and simulation companies around the world have switched over to make modifications with games engines rather than creating an in house proprietary engine. The return for the games engine creator is a royalty based system or a one of fee per license used in a company. According to 'Develop Online News', the largest contenders for free games engines on the market is the 'Unreal Engine' made by Epic Games Incorporated, the 'Crysis Engine' made by Crytek and 'Unity' made by Unity Technologies (Freeman. W, 2009).

With the visual qualities of next generation game engines, large interactive simulations companies such as Intelligent Decisions are using them to create military simulations rather than develop their own in-house simulator. As an example of using a games engine to simulate a military simulator, ‘Bohemia Interactive Simulators’ are using the games engine ‘CryEngine3’ to make a simulator called ‘*The Future Virtual Battlespace’* (VBS3, n.d.). It teaches military soldiers tactics, warning signs for improvised explosive devices and many other useful skillsets for soldiers before they are deployed or as a retraining tool.

Fig. 15, The Future Virtual Battlespace 2 (2012) products.bisimulations.com

On the NASA website they use the ‘Unity’ games engine to help explain to the public what the exploratory rover called ‘Curiosity’ is doing on the planet Mars (Jet Propulsion Laboratory, n.d.).

Fig. 16, NASA Jet Propulsion Laboratory (2013) mars.jpl.nasa.gov

The researcher reviewed the 3D models on NASA’s simulator as this engine was a possible chose of engine to use for the artefact as it had web browser functionality and NASA’s Jet Propulsion Laboratory was proof of how it works. The graphics in the machinery was created to a reasonable level of clarity but the researcher could see the use of polygon distribution was heavily optimised. It simulation lacked shadows and the digital surfaces that helped form the materials from metals to rubber where quite crude. The interactive user interface allows the user to view lots of objects of interest such as satellites, stars, asteroids, planets and much more. The user can track objects in space in their current position and give distance trajectories from earth which showed a high level of complexity in the simulation design.

As an example of a proprietary engine compared to an off the shelf solution that are achieving similar goals the researcher reviewed ‘The Solar System, Explore Your Back Yard’ and The Elements: A Visual Exploration as can be seen in the figures 17 and 18. According to the Touch Press website;

> “The aim of Touch Press is to create new kinds of books that re-invent the reading experience by offering information that is enhanced with rich media and that adapts dynamically to the interests and experience of the reader” (Touch Press, n.d.).

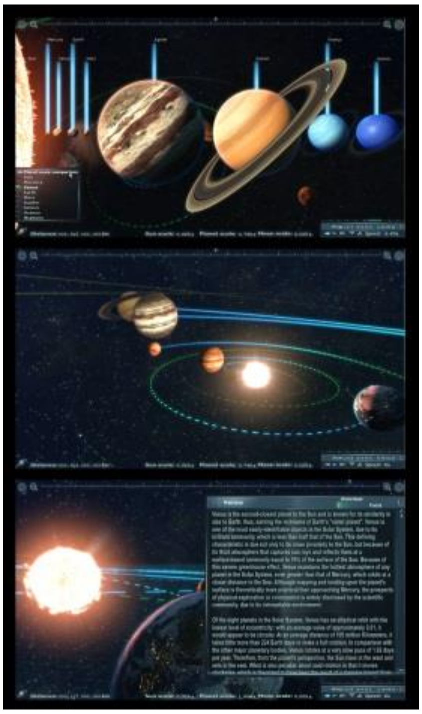

Fig. 17 *The Solar System, Explore Your Back Yard* (2012) touchpress.com

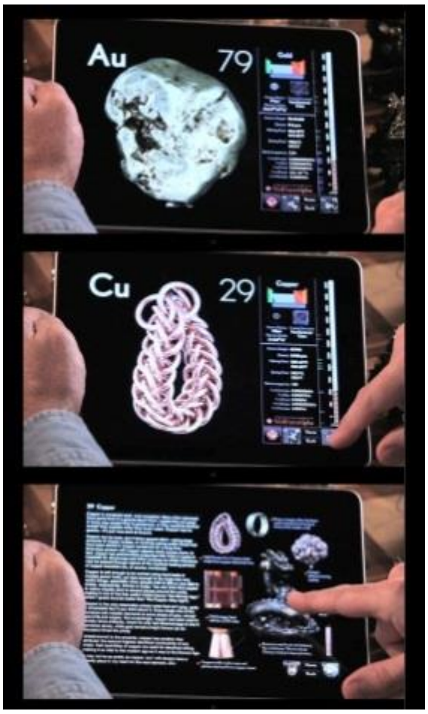

Fig. 18 *The Elements: A Visual Exploration*, (2012) touchpress.com

Both apps in the Figures 17 and 18 perform and feel very much like a digital book; they both have very different interactivity. This was due to the ‘The Solar System’ being created by modifying the Unreal Development Kit (UDK) Games Engine. This makes it a three dimensional experience and allows the user to visually view particular facts about planets such as gravitational pull with the use of interactive animation. The user can also bend grid patterns to show a planet’s effect on surface gravity and use a free camera to move around the object with click and drag functionality.

‘The Elements: A Visual Exploration’ is a visual exploration app that is educational and helps the user understand the periodic table. It is a flat 2D experience with flat 3D rendered images that can spin around on one locked axis in a 360 degree motion.

Both of these experiences allow for customer engagement and do so with touch finger playability which makes use of functionality such as pinch and swipe. They both work offline but with online benefits such as YouTube movies that can pop up.

2.5.1 Interactivity and 3D Simulation Software

A serious games division of Blitz games studios is called ‘TruSim’ (TruSim, n.d.), and according to their website;

> “TruSim creates effective, immersive and engaging training games using high quality 3D games techniques and technologies. Our games can be used on any platform PC, handheld device or console. They’re designed to be accessible and easy to use as well as being stimulating and challenging” (TruSim Triage Trainer, n.d.).

Fig. 19 *TruSim ‘Blitz Games Studio’* (2012) trusim.com

Figure 19 was from a case study in which a simulation has been used to train NATO and the UK emergency service medics how to treat blast victims, According to the ‘TruSim’ website;

> “Triage Trainer develops accurate decision making in the life saving skill of Triage. The game is set at the scene of an explosion in a busy high street and the player's job is to prioritize the multiple casualties for treatment”. (TruSim, n.d.).

This simulator has examples of virtual characters losing blood from the explosion, their skin colour fades and the characters are animated to look distressed, disorientated before hyperventilating and then finally passing out. This visual information allows medical experts prioritize the casualties.

Dr. Jack Choi demonstrated a real time, digital virtual dissection table on Ted Talks (Ted Anatomage 2012). The demonstration used a very wide variety of digital tools to accomplish a lot of features that allow the user to view inside a scanned body. The company that created it is called '*Anatomage'* and according to their Website;

> "Anatomage offers a unique, life-size virtual dissection table for the medical community. The Table offers an unprecedented realistic visualization of 3D anatomy and interactivity. Delivering accurate anatomic details, it is complementary for cadaver based dissection courses. For anatomy courses without cadavers, The Table offers the most realistic virtual cadaver. This cutting edge technology will help raise the standards of medical education to the next level" (The Anatomage Table Virtual Dissection, 2014)

Fig. 20 *Anatomage Table* (2015) anatomage.com

The Anatomage presents CT and MRI scan data in a touch screen method. From the image data the injuries look particularly useful for students, showing fractures and abnormalities in full 3D. This device would be particularly useful for students for training. For what the researcher is trying to achieve this 3D data would be too complex to show through a web browser especially with animation.

A company that specialises in training and education solutions for medical professionals is ‘Simbionix’. They have created their own simulation engine and according to their website;

> “Once the virtual model has been exported to the simulation environment, the physician can determine, evaluate and asses the appropriate access strategy, select tools and equipment, guide wires, catheters, endoprosthesis, etc.” (Simbionix, n.d.).

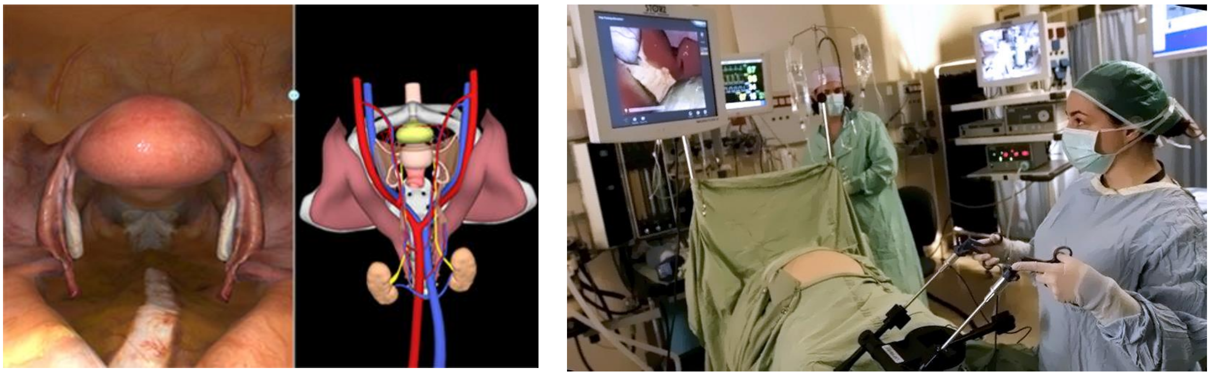

Fig. 21 *Simbionix Procedure Rehearsal Studio* (2013) simbionix.com

Simbionix has direct feedback to the medical practitioner in the form of a real time computer graphic screen mimicking a real life operation as well as having a physical operation theater around them, giving the user a close to life experience as possible.

A branch of ‘Blitz Games Studio’ called ‘TruSim’ made a game that helps enable health professionals to recognize the signs of patient deterioration, it’s called ‘Patient Rescue’.

Fig. 22 *True Sim Patient Rescue* (2013) trusim.com

True Sim, Patient Rescue tries to get the user to relate to 3D medical informatics and view the simulation of a digital person who is having a heart attack for example. The user can then be tested on making a set of correct or incorrect results which in a real world scenario could be potentially dangerous for a patient. The website has a warning "some users may find the visualisation distressing", this shows the level of realism in visual communication that is now possible with real time 3D simulation, in that it might offend a member of the public.

A company called *'Virtual Heroes'* creates immersive, 3D interactive learning solutions that they mention on their website contains 'high-fidelity synthetic virtual environments' (Virtual Heroes, Medical Project, n.d.). They have a range of simulations covering Government, Military, Industrial, Medical and Education. One of their products that concentrates on patient safety inside a medical theatre is called '3DiTeams'. The simulation has an option of team collaboration to test team coordination and virtual instructor led review.

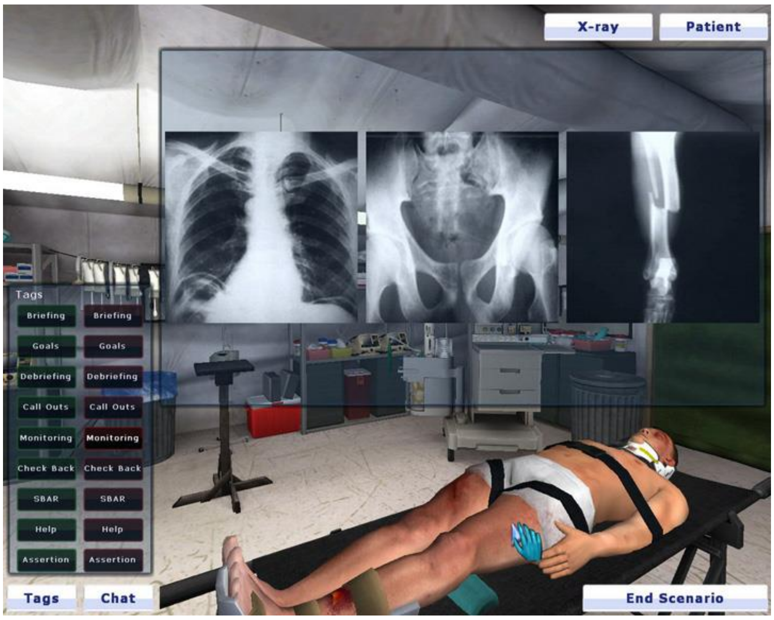

Fig. 23 *Virtual Heroes, Medical Project* (2012) virtualheroes.com

The website explains the simulation as "a first-person, multiplayer training application, used for medical education and team training" (Virtual Heroes, Medical Project, n.d.). The simulation has a range of approaches in the way it delivers content for example making use of X-rays, placing a patient in a medical theatre and giving the user an interactive options panel on the bottom left of the figure.

2.6 Serious Games, Medical Simulators

The researcher's artefact fits the genre Serious Games, the reason is;

> "Serious Games is a branch of video games that has introduced the concept of games designed for a serious purpose other than pure entertainment" (Anderson, et al. 2012: 1).

Under the term Serious Games there are many classifications such as Newsgames, Games-Based Learning, Persuasive Games and many more titles (Nielsen et al. 2011: 9). The closest classification that the researcher's artefact might fit into is Games for Health. According to Ritterfeld;

> “Over the past few years, Serious Games have become a hot topic at international conferences, conventions, and symposia. Interest in using games to educate, motivator, and change behavior has grown tremendously in a brief period of time, and by a truly international group of practitioners, civic leaders, health and human rights advocates, educators, gainers, and researchers” (Ritterfeld et al. 2009: 3).

To help expand on the category for Serious Games, Ma explains its different areas of expansion;

> “To date the major applications of serious games include education and training, engineering, medicine and healthcare, military applications, city planning, production, crisis response, just to name a few.”
> (Anderson, et al. 2012: 1).

2.6.1 The Games for Health Projects

The Games for Health Project was founded in 2004 with the goal of promoting games technologies for improving health and health care. It is funded partly by the Robert Wood Johnson Foundation and according to their website;

> “Our mission is to foster awareness of, education about, and development of games that make a positive impact on the health of communities and health care.” (The Games for Health, n.d.).

Since the organisations creation in 2004 they have just had their tenth conference in 2014, Boston. The project is run by a collective of experts in the field of medical research and games design technology. Many of the games that they promote cover a range of topics;

> “physical therapy, disease management, health behavior change, biofeedback, rehab, epidemiology, training, exergaming, cognitive health, nutrition and health education” (Games for Health, n.d.).

The Board members, staff and contributors are a collection of medical experts in their field. Together they contribute collectively, their skills range from a certified Anesthesiologist, specialists in treatment of children with severe injuries, physical therapists and specialists with spinal cord injuries and stroke or traumatic brain injuries. There are many more highly skilled and academically acclaimed people involved with the initiative. Debra Lieberman says in her keynote speech at Tedx;

> “There is skepticism to games so the research is necessary, certainly in the medical field. Doctors will not do any kind of treatment for patients for even health education without some evidence it works, how do they work? Why do they work? What are the psychological processes, cognitive events that occur within a game and so on”. (Can playing digital games improve our health, Tedx, 2009).

The Games for Health initiative has a very clear and simple development plan, which is to promote the results with certified medical experts and release the articles for use in publications. One such game the initiative promotes is called ‘Re-Mission’ and according to their website;

> “Re-Mission is a video game that gives young people with cancer a sense of power and control over their disease. It’s a fun, effective tool that supports treatment adherence and can be used in the clinical setting or at home by patients on maintenance therapy”. (Re-Mission, n.d.)

Fig. 24, *Re-Mission* (n.d.) re-mission.net

Figure 38.0 shows screen shots from people using the game, it helps users understand the medical vernacular based around their condition. It allows them to play a game that shows the long term positive befits to chemotherapy and other prescribed treatments. The Games for Health team then research the self-efficacy in the patients, as the organisation believes *‘Re-Mission’* gives patients positive emotions towards their prescribed treatments. There are many publications on the user results from ‘Re-Mission’. In an interview by the creators of the game they mention;

> “The current results suggest that a carefully designed video game can have a positive impact on health behavior in young people with chronic illness”. (HopeLab, 2007)

As the games industry has constantly pushed the boundaries of visual quality. The graphics quality of screen images from games engines is now at a stage where it can be used with enough clarity and accuracy in its visual representation of the human body to be used as a tool to teach medical students and the general public about medical conditions as can be seen with ‘Virtual Heroes’. According to Graafland;

> “The application of digital games for training medical professionals is on the rise. So-called ‘serious games’ form training tools that provide a challenging simulated environment, ideal for future surgical training. Ultimately, serious games are directed at reducing medical error and subsequent healthcare costs” (Graafland et al. 2012:1).

2.7 3D Through a Web Browser

With the release of 64bit, Direct X 11 computing in 2009, the standard for real time graphics was raised. It took time for companies and the public to update their software and hardware but as they did it allowed for better 3D graphics due to computers coming with graphics card capable of performing 3D graphics.

One of the most used 3D embedded web based technology that people would recognise is Google Earth. This standalone product has been downloaded over one billion times according to the ‘Google Earth website’ (Google Earth Blog, 2011). This piece of software has given the public an understanding of the benefits to streaming 3D graphics as cities, roads and 3D buildings load up in real time from a cloud based source through ‘Google Maps, 2015’. The creators however have to keep in mind the time it takes to load

3D models versus the quality of the 3D models, a practice in the games industry called 'Level of Detail' (LOD).

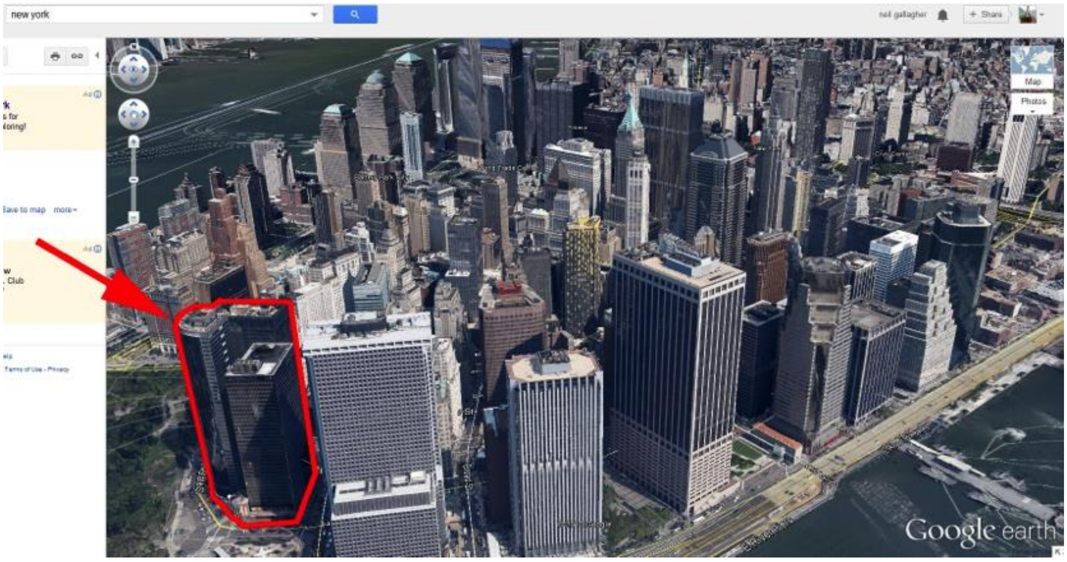

Fig. 25, *Google Earth Website, 3D view of New York* (2014) google.com/earth

Figure 25 was a snap shot from Google Earth, 3D content is embedded into the web browser enabled by downloading the Google Earth plugin.

There are many successful games that have been launched using embedded computer games using web based technology. To give a few examples there was 'Battlestar Galactica' (Syfy Games, 2013), 'Dead Frontier' (Creaky Corpse, 2013), 'Interstellar Marines' (Zero Point Software, 2013). These games are sophisticated mass multiplayer online role-playing games. They show the high level of complexity that is possible through an embedded browser. The only disadvantage was they are quite slow at uploading the game into the browser due to the amount of content that is being delivered but this can be resolved to some degree with faster internet connections.

The Ford website has embedded 3D content to help the user view and customise car models. There are a number of options for viewing a vehicle: 2D photo, film and 3D models. Ford has chosen to use Java to enable a range of 3D cars to appear in the browser. There are a number of issues with using Java: the plugin was not native to 3D browsing, it was slow to install and in this study antivirus ‘AVG’ came up with a warning on the researcher’s PC showing a notice that Java is trying to access the Internet every time the website was accessed. These kinds of issues might be enough to deter users who are not very computer literate.

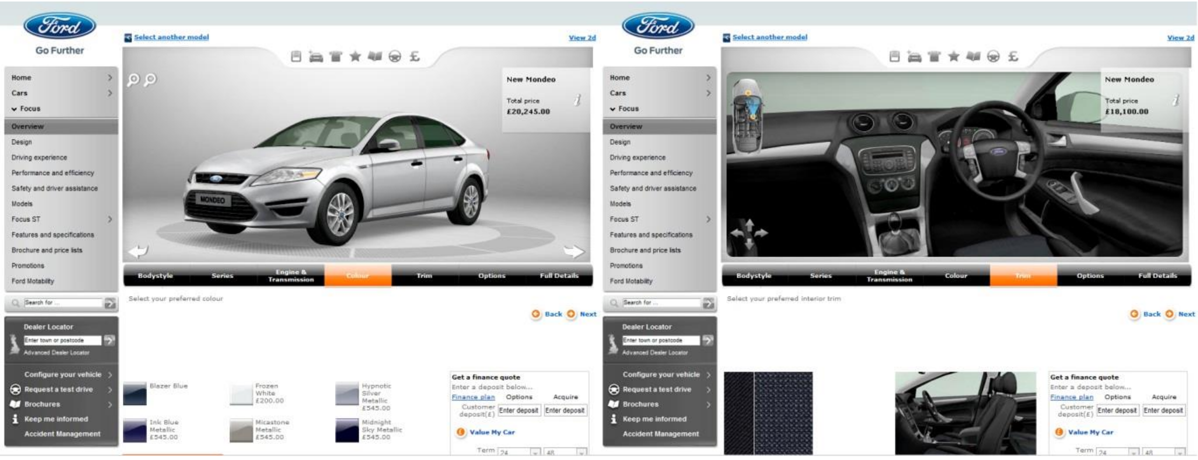

Fig. 26, Ford Motors Website (2012) ford.co.uk

In Fig 26 the 3D car becomes available when you chose to ‘configure your vehicle’. From the outside of the car the camera is locked, which allows Ford to dictate the best possible view without letting the user break the camera. The experience feels like a hybrid of a rendered cinematic but with some 3D interaction. The camera can instantly move to a position inside the car. Once inside the user is free to pan the camera around but it is very restricted as there is no dolly, track or zoom and just a limited pan from left to right and very little tilt.

2.7.1 3D Medical Informatic Systems Through a Web Browser

A company called ‘Zygotebody’ has created an online medical communications simulation. The software is an anatomy browser and does not explain medical ailments. According to their website it help informs “broadcast television, films, computer games, educational software, and medical illustrations and animations” (Zygotebody, n.d.). Zygote Body allows manipulable 3D anatomical models that work through a web browser. According to the Zygote website,

> “The foundation of this collection starts with an entire skeleton model based on CT scans, and upon which all the other systems fit together. This collection has been in development since 1995 and is continuously being upgraded and improved upon”. (Zygotebody, n.d.).

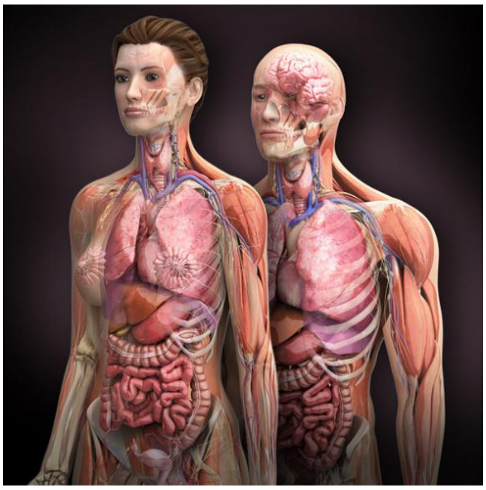

Fig. 27, 3dscience (2011) 3dscience.com

Fig. 28, *Zygotebody* (2012) zygotebody.com

To use Zygotebody the user has to create a login account. Once the user has logged in the software introduces the user to the monthly costs. There is a free option which has a limited service. After creating an account the software was easily accessible with a very clear user interface. The 3D digital human body takes around twelve seconds to load on a ten megabyte connection and then there are some further texture streams once the digital character has fully

loaded, such as the face texture. The camera rotates on two single axes; left and right and up and down. It has a slider that controls transparency to help reveal the digital human body from the outside skin layer to the muscle and bones, circulatory system, organs and nerves. The clothing did not allow the researcher to review what was under the garments. The transparency of the clothes and skin happen at the same time. Google are possibly avoiding the subject of nudity. The product is primarily an anatomy browser so it does not have any audio, lighting control, animated mesh data, there is not any camera paths (like google earth), no post process effects and no animated schematic break downs.
It was created by Google Labs but is now maintained by Zygote, which may explain why some of the camera functions in much the same way as Google Earth, for example when the user performs a name search, the browser zooms towards named body parts.
There was a problem with Zygotebody, when the researcher tried to view the product in Internet Explorer the browser said: “This product uses WebGL, which your browser does not appear to support”.

Another medical informatics tool is, “Bio Digital Human, a publishing platform for visualising anatomy, disease, treatments and health information - all in interactive 3D.” (Blausen Bio Digital Human, n.d.).

Fig. 29, *Bio Digital Human*, (2014) biodigitalhuman.com

Bio Digital Human is free to use but there was a premium charge of six dollars per month for more content and features. The product is optimised with no frame rate or load up issues as it starts with the display of a digital skeleton and then the user has to upload human body parts by selecting them on a table to the left of the screen. There are small data loads for each digital human body part. The 3D models are very clear and the user interface is easy to use and navigate. There was a lot more to explore in *'Bio Digital Human'* compared to 'Zygotebody' body as there are lots of small icons and each has a detailed functions describing body parts. The detail in the 3D model is more complex than 'Zygotebody'. The camera is able to rotate on any axes around a chosen body part. There is a medical ailment browser and it zooms into the affected parts, and it explains the ailments with text.

'Zygotebody' and 'Bio Digital Human' are two real-time examples that work through a web browser. They are both functional and good anatomical learning tools.

2.8 Software Development Methodologies

The researcher set out in this study to see if the technical advances in 3D graphics delivered through web browser could be an effective way of delivering medical health information. Choosing the appropriate game engine for this task was a matter of researching the current market. This meant gathering information from various sources such as websites, forms, magazines, books, conferences and speaking to old work colleges working in the games industry.

Websites such as 'Develop' listed the most popular games engines with Unity and unreal coming in top place (Freeman. W, 2009). Targeting the most relevant and popular forums that have regular and up to date posts by technical game industry staff. The 'Polycount' game forum for example proved to be a valuable source of information, Polycount (n.d.). Many people in forums have signatures below their posts mentioning their current position, this is useful when it is an engineer from a company that is communicating or answering a question. When information can be disclosed forums can be ahead of game company websites, magazines and publications due to the rapid proliferation of games consoles, tablets, smart phones and virtual reality headsets. *'Wikipedia'* has an extensive list of games engines, it also conveniently lists all the engines functions such as Web Browser support (Wikipedia Games Engines 2015).

Going to Animation, Effects, Games and Transmedia conferences such as 'Film and Media Exchange' (FMX 2015) in Stuttgart, 'Develop Conference in Brighton' (DCB 2015) and 'Electronic Entertainment Expo' (E3 2015). A conference can be an insightful source of information not only for the talks but also for the networking opportunities they can bring. Once information is obtained and documented the best way to review a games engine is to downloaded it and spend some time reviewing the product. Testing the interface and making sure the pipeline functionalities actually work. Weighing up all the advantages and disadvantages to the choice of games engine enables a developer to come up with the best software product analysis for what the developer wants to make, each engine allows for slightly different specialty's.

The researcher wanted to make use of his experience in games industry techniques and test if it's possible to create a tool to help inform people about ailments as set out in the Research Questions. In the case of this study, asthma was chosen and was to be displayed in an interactive manor inside a web browser. With HTML5-WebGL, JavaScript and web browser vendors collaborating with games developers and new technologies are starting to appear on the market to allow for more 2D & 3D content on Web Browsers (Echterhoff 2015). The researcher wanted to explore many of these new features for medical communications and to see it is possible to communicate effectively to a target audience. Modern computers and smart phone devices make use of hardware-acceleration;

> "Many modern browsers now take advantage of a technique known as hardware-acceleration. This means that the browser can use the Graphics Processing Unit, or GPU, to speed up the computations needed to display both 3D and everyday 2D web content" (Chan et al. 2015:6).

Games engine technologies allow for multiplatform capabilities from a single development tool, this means being able to export to games consoles, tablets, smart phones, VR head sets, and Web Browsers. This study focuses on 3D medical information being presented through a Web Browser to a target audience, asthma sufferers. In order to understand the human communication in context to the prototypes design, user testing was set up with asthma sufferers. According to Benyon. D;

> "Design is a creative process concerned with bring about something new. It is a social activity with social consequences. It is about

> conscious change and communication between designers and the people who will use the system." (Benyon, 2010: 146).

The prototype was to be tested on a user group, in the case of this study 'asthma sufferers' and the results where to be documented on how the interactive technologies performed so the researcher could understand the communication between the product and the user.

According to Benyon;

> "Understand what the requirements are; Understand the range of requirements generation techniques; Use techniques for understanding people and their activities in context; Document the results as requirements on interactive technologies and services." (Benyon, 2010: 146).

By getting a range of asthma sufferers the requirements in understanding any problems with the software artefact will surface from the user testing. Medical professionals were also user tested to help validate the accuracy in the medical simulation to help further validate this study.

In order to gain authoritative audio and visual material to use in the medical browser the researcher approached the NHS and asked for permission to take information from their website for the use in the researcher's prototype. The NHS granted with an agreement document via an email which can be seen in the Appendix.

2.9 Agile Software Development Methodologies

The researcher worked for a company called 'Rare Games Studio' (1997-2003), Rare (n.d.). They are a games studios that produced software for Nintendo. The software development was very much management driven from the CEO's and the lead Programmers/Artists desire for delivery of content driven resources. At that time the development team delivered content on calendar dates in order to meet a final deadline. While this management style is flexible in small teams as the company grew in size this was not very agile. The development process could not cope with blockages which can come in the form of a range of issues, for example, team members migrating companies, software and hardware failure, publishers contract deliverables and their own manifesto which can adapt to audience trends, this is a snap shot of what can happen to a software development team. A new management process was implemented to control the software development as the company that grew from thirty people in 1997 to around two hundred by 2001. According to Brown;

> "To understand what it means to practice an Agile form of user-centered design it is important to have a sense of what exactly Agile means and where the term came from. Since the Agile methodology has a deep, rich history and is continually evolving, it has become the subject of many books, blogs, white papers, conference presentations, and websites, all of which have their own take on the value system and its methods."
> (Brown, 2008:1).

When Microsoft bought out *'Rareware'* in 2002 new forms of training in software development was introduced and 'Scrum Management' soon became the main software development process for the disciplined development process in the creation of computer games. According to Holcombe;

> "When we embark on a software development project, the initial and some would say the hardest phase is that of determining the requirements-finding out, with the client, what the proposed system is supposed to do." (Holcombe, 2008:2)

The researcher also worked for 'Kuju' in 2006, Kuju (n.d.). Scrum Management was the same agile software development process as already experienced at Rareware, Microsoft Games Studio. This made the process of embarking on new products relatively straight forward for programmers, designers, musicians, producers artists, and other core staff members. It made the core work flow a familiar process and for those that did not know about

Scrum Management, a matter having some training to become a proficient member of the team.

2.9.1 Scrum Management

Experiencing Scrum Management at both Kuju and Rareware, Microsoft Games Studios proved to be an agile process for accomplishing a complex framework for staff and software development in order to reach a common goal. According to Pries and Quigley;

> "The Scrum approach strips away non-value added activities and impels delivery by focusing on the immediate details. It is not possible to interpret Scrum as anything as anything but disciplined development model." Pries and Quigley (2010:2).

Scrum Management is particularly aimed at projects where the end user may not know exactly what they want. Targets can change in replacement of new software features taking new priorities, this help ease issues such as blockages and helping to resolve the overall Gantt Chart targets, also known as "Sprints" for the short term goals and "burn downs" for the ongoing process. Priority to variable changes has to be addressed in order to meet regular Sprints.

The researcher's experience on larger teams worked by having regular meetings every morning at a regular time to explain the current software development process to the allocated Scrum Master, a series of questions would be asked, for example, what did you do yesterday, what are you doing today, have you any blockages, are you waiting on any software. Then the Scrum Master who is normally a senior member of staff would meet with the team leads to give an overview of how the development process is moving and they would go and inform the CEO and they would inform the stakeholders or publishers.

To sum up the researcher’s experience of scrum management, from a junior artist through to senior member of staff. Scrum provided to be a clear communicator for team members, organizing milestones, educating everyone involved in the project from the stakeholders, CEO’s, Lead Programmers, Artists, Designers, right down to the junior members of the company. It is a very fast way of negotiating priorities and explaining any possible blockages to the team. There are many process in scrum management that can be implemented for a single developer. For example managing a product backlog and signing off development goals, keep unit testing in place, retrospectives in terms of change being welcomed, this could be in the form of a software update that can both help development but also cause a blockage, never settle into a rhythm always look for the new software developments.

2.10 Survey Methodologies for Software Evaluation

The software evaluation will have a number of stages. Early development will be to see if it is possible to answer the first research question and find a games engine that can deliver 3D content into a browser. In order to find the right games engine research will need to take place by looking on game company websites, reading though magazines and publications, posting on forums then downloading the engines and practicing with them to see what they are capable off.

If the artefact is based on asthma it will be need to be user tested on asthma Sufferers as the target user. This will mean ethics approval will need to be applied for in order to receive a protocol number before any user testing can take place.

While the ethics application is being processed a pipeline will be created to make sure an independent developer use the games engine and export from the engine to a web browser. This will help highlight any blockages such as animation not working, having to learn some programming, seeing if the graphics is high enough in resolution to show the human form and the internal organs and bones.

Once the researcher is confident that the first research question can be answered the next process will be to customise the games engine into a simulation. The software will need to lose all the gamification from the prototype. Once a working porotype is working and the ethics clearance is approved the user testing could take place on asthma sufferers to test the artefact for its communication deliverables.

The artefact can then be tested on medical Professionals for its accuracy. The last stages will be to gather all the information and summaries the results into tables to get a better overall view of the results.

While all the above research will be taking place the research will need to write it all out into a research paper to help support those arguments.

2.11 Literature Review: Summary

There is long history of medical illustration and visualization. There has always been tensions between representational and abstracted styles in terms of medical communication of the human form. There was a dissatisfaction with purely 2D illustration and physical models as a way of communicating effectively as they can never replace the real human body but at the same time they have always been present as training aids.

In the digital era these tensions where replicated and reproduced with technology. Gradually technology has become available to allow medical visualization to be viewed on nonspecialized equipment through the use of 3D graphics inside a web browser.

3.0 Methodology

This chapter sets out the methodological approaches in the creation of the software artefact. The software development project came from the researcher having experience of a close family member wanting more information on a medical condition, and feeling that a 3D web browser project could complement pamphlets and doctors' advice to help understand a medical condition. Also upon further research on the subject there is an import social need for greater health communication. The researcher thought the technology was available and ready to provide a complementary health information tool via a web browser. The research project was aimed at complementing the current methods of health communication via transdisciplinary strategies and using web browser technology for distribution methods.

An early prototype was built to show that 3D interactive content with audio and animation data could be delivered inside a web browser as a communication tool. Various games engines where tested and Unity became the engine of choice, which is discussed further in section 5.2 Delivery Technology.

Once a working prototype was achieved the researcher moved the focus to the Statement of Requirements. There were four main areas to focus on, Target Users, Content, Delivery of Platform, and Functionality. For each area of focus the researcher developed the content from using various sources, personal experience, knowledge of sufferers, knowledge of available technologies and the information received from the first prototype. This allowed the researcher to develop a feasible application software artifact that would meet the project outcomes.

A target user of asthma sufferers was chosen as case study for the focus of the artifact, it gave a firm idea to build the structure for the artifact. The aim of which was to test the feasibility of creating a medical simulation contained inside a web browser, then test the results on asthma Sufferers. Medical experts were also approached to test the contents accuracy, and results from both tests validate the research study.

3.1 Project Definition

The software artifact was built to see if it is possible to make use of current advances in 3D simulation software and make a working 3D medical simulation using embedded 3D graphics that works inside a web browser. The artifact has the traditional interactivity that comes with simulation software such as point and click interactivity, animation data, audio and free camera rotation. It has been produced in a small amount of megabyte (MB) data to allow for fast upload to help with the user experience.

For this case study asthma has been chosen as the subject matter in the artifact. This was due to personal experiences and seeing firsthand the devastating and life threatening effects it can have on sufferers of the disease. The researcher's Sister, friends and close family members and a friend of the researcher died of the disease at school.

The next stage was to refine graphics fidelity from the original rough prototype so it could be reviewed for its effectiveness in communicating with patients about their medical conditions, and test its usability and functionality. Then medical experts reviewed the simulation to test its effectiveness and help with the validation of the project.

Reviewing the success of the study allowed the researcher to analyse quantitative data and help validate this study. The opinion from the asthma sufferers and medical experts helped shape any limitations of the study and give trajectory for further development of the project.

3.2 Identification of the Statement of Requirements

The researcher developed the specification of software requirements into four main areas and the Target Users, Content Deliverables, Delivery of Platform, and Functionality.

These prerequisites gave focus for the researcher to achieve clear, defined goals. The researcher then developed the artifact using various sources from experience, knowledge of sufferers, knowledge of available technologies and the information received from the first rough prototype. This allowed the researcher to develop a feasible application software artifact that would meet the project outcomes.

To help with gathering an authoritative source of information the *'National Health Service'* was approached for permission to use content from their website; the researcher was granted permission in the form of an emailed document (see appendix).

3.3 Software Development

Reviewing the various software development products relating to medical simulations and other related game engine technologies in the Literature Review allowed for a detailed look into what is in development and what is currently on the market. Developing a working pipeline and recording it in the Technology Rational allowed for a rational decision making process to be considered; this included reviewing and learning various off the shelf games engines before deciding the best approach for the creation of the software artifact. Customising an off the shelf games engine allowed for fast iterations of software development.

Scrum Management was an agile software development work methodology that the researcher was involved with while working at *'Rareware'* on various Nintendo products that also involved a partnership with Disney. Scrum became more widely used at *'Rareware'* when Microsoft purchased the company. Another games company the research worked at was Kuju Games Studio, they also had scrum management as a software management tool and the publishers included *'Microsoft, Sony, Nintendo, Activision, Warner Brothers and Sega'*. It was expected by those publishers that goals where set in a Scrum management style and they could drop into everyone deliverables to see how the overall production was going. *'Kuju'* gave regular training for staff members in accordance to the publishers recommended pipeline and ethos. The main stability in the processes between studios and projects was the Scrum Methodology. According to Pries and Quigley;

> "The scrum approach strips away non-value-added activities and implies delivery by focusing on the immediate details. It is not possible to interpret scrum as anything but a disciplined development model" Pries and Quigley (2012:1).

As the final software artifact was a research project and not built for a client the researcher had to use past experiences while based at Games Development Studios. This helped to set personal agile software development goals and place them against goals set on a Gantt Chart to meet the software goals known as 'Sprints' in Scrum methodology, this involves a process of repetition of design, development, implementation and analysis every four weeks, then adjusting the goals on the timeline in order to reach a working prototype. The researcher chose Scrum Management as the Software Development Methodology. There are other models that include "Waterfall Model, Spiral Model, Iterative and Incremental development, Process Improvement Models and Agile development" (Larma, 2012:11). The reason Scrum was chosen was due to the researcher's personal experience with the methodology and according to Larma's view on Scrum methodologies is that; "Each one has its pros and cons, and it's up to the development team to adopt the most appropriate one for the project" (Larma, 2012:6).

3.4 Validation

The validation was broken down into three areas; first was the functional testing and checking for bugs. The next area was the usability testing and effectiveness on communication to asthma sufferers and the accuracy which was tested on medical professionals. The last was a review against the statement of requirements.

The functional testing was an ongoing process as each update to the software can bring crashes and new limitations of the software can be expanded to bring new functionality to the 3D software.

Once the artifact moved from being a prototype to a functional artifact usability testing and effectiveness of its communication could be tested. The consideration of the prototype was aimed at communicating a medical condition to public users looking to gain an understanding of a medical condition. The users skill level in 3D simulation technology was going to be a broad spectrum and as such had to be considered by making the overall simulation not too complicated that the user would get lost or put off with the interface or 3D graphics. The section of the simulation with free camera movement accompanied with point and click selection functionality and voice audio was created to see if it was possible with web browser technology. At the same time making sure the overall usability of the simulation was easy to use, as tested in question 10 of the user survey, see section 6.3 Target User Survey Results.

The development process of performing a User Survey test allowed the researcher to test the ‘Research Questions’ and test the objectives to a select target audience of asthma sufferers and help test the effectiveness in its communication. According to Caddrick;

> “A usability test clearly communicates what was uncovered in the user research. A great report enables the project team to discuss actionable solutions that improve the product or service for the users.” (Caddrick, C 2011:265).

As Caddrick suggest the survey results will be an opportunity to review the answers and work out how to improve the product for future development. The validation process was achieved with functional testing and the goals were driven from the Statement of Requirements and Research Questions. As asthma was chosen as a case study for the focus of the medical browser artifact user testing was performed on asthma sufferers and medical experts to help validate the project. The overall results from the User Survey can be found in chapter six, Evaluation.

3.4.1 Functional Testing

Functional testing of the software development project was produced in two stages. The first stage was the creation of a working prototype where the researcher could test if the process of the required content could be produced. According to Everett;

> "With functional test tools, there is an automated comparison of expected versus actual data or screen contents or report contents. Either the results compare exactly (pass) or they do not (fail)"
> Everett and McLeod, (2008: 160).

The second stage was for test subjects and medical professionals to user test the artifact and allow for the test subjects to make responses to a set of questions with a Likert Scale to help the review process. Open questions allowed the researcher to capture additional information.

3.4.2 Usability Testing

In order to find user test subjects a blanket email was sent to University of Hertfordshire students. The email explained that a researcher was looking to user test a 3D medical simulation working inside a web browser; the user test subjects had to suffer from the condition of asthma as it was a prerequisite for all participants. The first six candidates coming from a range of courses across the University where chosen for the study, an extra subject was put on standby but not need as all test subjects turned up for testing.

In line with the Ethics Protocol the questionnaire was anonymous of any personal details such as name, sex and age and the user tester was given a Respondent ID number. All the personal information is stored securely on a private server and destroyed at a later date. An allocated time slot from 5pm-7pm was open for students to come and test the browser for its effectiveness on communicating the condition of asthma. Six computers where set up in a computer laboratory at the University of Hertfordshire

In order to find Medical professionals the researcher emailed around one hundred surgeries and posted on website forums such as (HealthUnlocked, 2015). Many of the emails where targeted at hospitals that specialised in asthma care and other various respiratory diseases. Once contact was made, communication took place for a doctor and Nurse to review the software artifact and the questionnaire was filled out by them in person.

3.4.2.1 User Testing Design

For the user test the plainest of rooms was chosen and booked. In this room it was free from any posters with only white walls and fifty PCs. Only the test subjects and the researcher where allowed in the room during the test conditions. At the far end of the room, furthest away from the corridor to help with outside noise pollution, there were six PC's set up with head phones and an a A4 sheet of paper with two hyperlinks; the first to the medical browser website and the second to the 'Esurv' (2015) website which contained the survey. The test subjects spent around 30 minutes browsing the software before filling out the questionnaire. The questionnaire was set out with the system of Likert Scaling. According to Brace;

> "The technique presents respondents with a series of attitude dimensions
> (a battery), for each of which they are asked whether, and how strongly,

> they agree or disagree, using one of a number of positions on a five-point scale" (Brace, 2012:73).

The questions can be broken down into four categories. Firstly the effectiveness of its communication, secondly usability and functionality, thirdly comparisons to other forms of health information such as pamphlets, and fourthly respondent data for research analysis. The researcher was on standby but not needed throughout the user testing.

3.4.2.2 Ethics

The ethics was dealt with in accordance to the University of Hertfordshire code of conduct though the Faculty of Science, Technology and Creative Arts. The process allowed for a detailed explanation of what was required by the test subjects, which was a software data analysis and survey. The aims and methods of the research was then reviewed appropriately and vetted within the School by the Ethics Comity Board. Once the board gave approval and an Ethics protocol number was approved, and given to the researcher, codes of conducts were adhered to throughout the planning of the questionnaire and study. For example, the test subjects had information explained to them about how the research data and how the information was going to be stored securely on a private server and destroyed after completion of the study. The survey asked for the test subjects to click an agreement of acceptance for participation box which was at the start of the questionnaire. It also explained that participants could leave at any time should they not wish to take part in the survey. The names of the test subjects was translated into code numbers though the 'Esurv' (Esurv, 2015) website to help with data protection.

3.4.3 Accuracy

The accuracy was measured in two ways; the first was a user testing survey on test subjects that were asthma sufferers. They reviewed the 3D medical simulation working inside a web browser that explained the condition of asthma, they saw how the simulation explains the effects of asthma inside a digital human body before spending some time answering the questionnaire. The second study was to user test the artifact on medical experts so they could validate the contents accuracy.

3.5 Chapter Summery

This chapter discussed the methodological approach to the researcher's software development project. It explains how ethical consideration was adhered to in respect to the asthma sufferers and medical professionals that volunteered their time for the user testing questionnaire to take place. It outlines how the data was collected and mentions that an evaluation of the functional test results are analysed in chapter six of this study.

4.0 Identification of Statement of Requirements

The researcher will build a real time medical simulator that will work through a web browser. It will be user tested on asthma sufferers to test how it communicates to a target audience. Medical professionals will review the artefact in a separate study to user test the product for its accuracy.

Viewing health communication media content inside a websites such as the National Health Service (NHS, n.d.) or the World Health Organization (WHO, n.d.), these websites have still images or embedded movies such as Youtube. Can a 3D web browser artefact follow these traditions but allow for a real time 3D simulation with interactivity. It will be relatively bug and crash free and users will not get lost in its interactivity.

4.1 Target User

The researcher wanted to test if a 3D software artefact working inside a web browser could communicate to non-specialist users working within a browser. Rather than purchasing and downloading software artefacts, as was reviewed in Chapter 2.4 with examples from 'Blausen Medical Communications' and '3D4Medical'. The Researcher felt that due to technical advances it may now be possible to communicate to a target audience with 3D content within a browser.

When designing any browser based software tool it is important to target a user base before any creation process starts. According to Grady;

> "Customers, the ultimate users of systems, or their procurement or acquisition agents, are capable of initially identifying the need for a new or significantly modified system only in the most grand terms" (Grady, 2006: 17).

The artefact needed to communicate effectively and could complement current health communication. Technically it would be placed inside a web page in much the same way as viewing a still image or embedded movie but the artefact would be a real time 3D simulation with some interactive content.

Once the idea was tested with some early prototypes to give the project feasibility, the next stage was focusing on a target user. The target users were asthma sufferers due to the software artefact explaining the condition of asthma.

The researcher wanted to test the medium and see how much it could deliver to the target user in the form of interactivity, audio, colour, lighting, animations, camera control and lens control. As the users where going to be asthma sufferers they could have already had some exposure to medical information in the form of Doctors advice, possibly pamphlets, magazines, internet images and animations. The researcher wanted to encapsulate some of this data and place it into one communication device. According to Grady;

> "Through observation of their current products and processes of that of their competitors of adversaries, they can see that of their competitions or adversaries, they can see that certain needs are not then being met by the systems available to them" (Grady, 2006: 5)

By reviewing the 3D medical and simulation products in the Literature Review the researcher was able use this information to shape the user content for the artefact. The certain needs that where not then being met in Bio Digital Human was cinematic content of medical ailments to help better explain the subject.

By user testing the device on the target audience whom may have been exposed to other forms of health communication about their condition will help compare the artefact to other forms of health communication.

4.2 Content

When designing the medical artefact the content was driven from the research questions. The feasibility in answering the first question was answered with an early working prototype that was delivered inside a website.

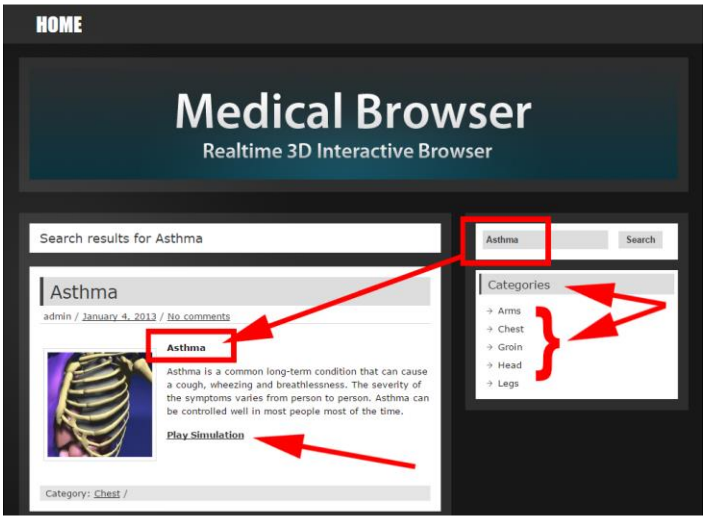

Fig 30, Artefact Website (2015) medical.mudboxcentral.com

By placing the artefact inside a web browser allowed the product to have search capability through hypertext markup language (HTML). This enables library functionalities to be designed and built. This is important as it allows the user fast access to a range of common ailments that can occur in a particular body area. Alphabetical categories can be listed or straight forward searches inside a search bar, as can be seen in Figure 41 with asthma being searched for. According to Benyon;

> "Graphic design and information design are particularly important issues of information layout and the understandability and aesthetic experience of product. Human- computer interaction has itself evolved many techniques to ensure that design are people-focused." (Benyon, 2012: 20).

The content design for the original artefact was achieved by compartmentalising various communication tasks into a check list. The task list was to perform animations, audio, lighting, camera control, interactivity, lens control and an important task was to see if the games engine working inside a web browser could contain enough mesh data to symbolise a digital human body.

Once the tasks proved to be working the focus moved to the second question. Can a system be built that could communicate effectively to a target audience. For the focus of this study asthma sufferers were chosen. The researcher started by gathering authoritative information on the condition of asthma from websites like the ‘World Health Organization’ (WHO, n.d.) and the ‘National Health Service’ (NHS, n.d.) which contained animations and written information on the subject. Pamphlets were also picked up from the doctors surgery and the researcher discussed the subject on open forums such as (Heath Unlocked, n.d). The researcher also discussed the idea of the medical artefact with asthma sufferers such as work colleague Martin Bowman, who was a long-term sufferer of asthma, his views were as follows;

> “An interactive tutorial would be a fantastic benefit to asthma sufferers, especially children who have a hard time learning how to use an inhaler correctly”. (Bowman, 2013)

Once all this information was gathered, the process of creation on the main artefact was started. The method was to keep the focus on the direction of asthma sufferers, their family members and other non-specialist users.

4.3 Functionality

Software interactivity can be exponentially expanded on, the aim of this study was to prove functionality such as free rotational camera movement, and point and click on three dimensional models and images could work to deliver content through a web browser. The aim was to get the overall simulation to a stage that could communicate effectively to asthma

Sufferers. The graphics needed to be coherent enough to allow medical professionals to validate its content as this would help answer the research questions.

As the target user group were going to be non-specialists the user experience of the artefact was to be made simple and interactivity a click and play scenario, with areas of interactivity to add more information on selected targeted areas. The approach was to allow the user to go in two directions at the start of the simulation via two button options. One direction would give the user free rotational camera movement around an organ with added interactivity by selecting a range of organs around the trachea and the trachea itself. Once an organ is selected a 3D cinematic accompanied by audio and animations would proceed to help explain the visual content. The other option would be more of a cinematic lead approach explaining the condition of asthma. The idea was to break the simulation into small sections allowing the user to repeat, skip to the start or go onto the next section. In areas there would be imagery for the user to click on and find out more about a particular image or organ allowing the user more information about their selection with further audio, imagery, text or all of this displayed in a cinematic.

The use of colour and texture detail for the artefact had been chosen on the basis of optimisation allowing for fast upload times. The photographic projection of a real human head was captured from photogrammetry data then re-projected onto a digital human head as can be seen in Figure 42.

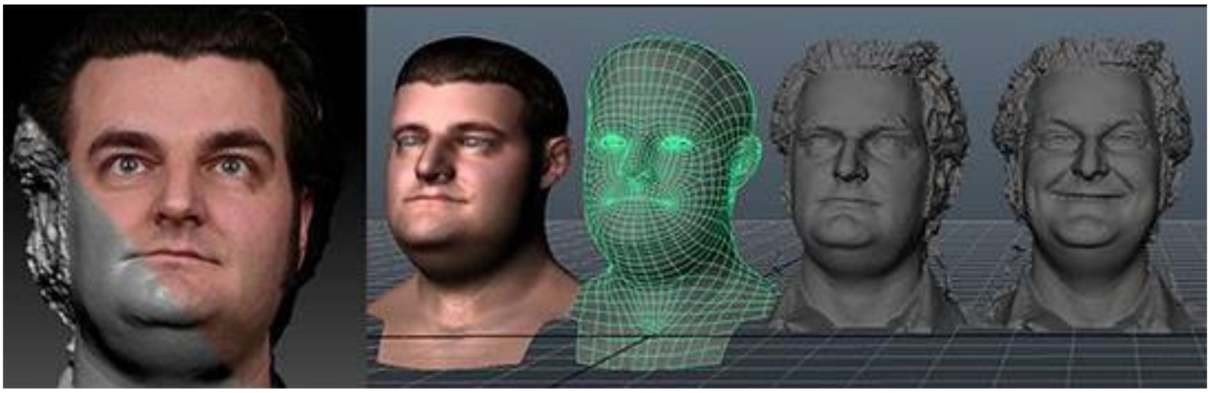

Figure 31, Neil Gallagher (2013) Digital human head

The texture detail in the digital face model needed to communicate a visual representation of a digital human head. The reason is down to people mainly fixating on the face rather than the body. According to Judd;

> "These objects reflect both a notion of what humans are attracted to and what objects are in our dataset. By analyzing images with faces we noticed that viewers fixate on faces." (Judd, *et al.* 2009:4)

Fig 32. *Regions of Interest faces*. Judd, et al. (2009) people.csail.mit.edu

The rest of the digital human body and the internal workings had flat colours driven from vertex paint which had a digital value of red, green and blue. This helped with the optimisation of the prototype; keeping the overall memory size to less than ten megabytes was of paramount importance for quick load times, (this is discussed in more detail in chapter 5.0 Realisation, section of this study).

4.4 Delivery Platform

To find the best delivery platform for the artefact the researcher reviewed games engines that delivered content inside a web browser, there is more detail on this topic in chapter 5.0 Realization. Currently there are compatibility issues between the web browsers as to which direction to go to allow for 3D & 2D content to work through a web browser. According to Unity Engineer, Jonas Echterhoff who gave a key note speech at the 'Unite Europe 2015' conference (Unite Europe, 2015), he talks about the security issues of allowing arbitrary browsers connecting to arbitrary functions on a computer. He goes onto talk about the roadmap for the future and that browser vendors need to work together to help improve web browser technology and performance.

WebGL is a JavaScript application programming interface that allows 3D and 2D graphics to appear through a web browser without requiring any plugins, (Parisi, 2014: 1). Currently, Google, Mozilla, and Opera all support Web Graphics Library (WebGL) to allow for 3D and 2D content. Microsoft have their own system called Silverlight, which is their own in house proprietary solution for 3D and 2D. According to the Microsoft website; “Silverlight is a powerful development tool for creating engaging, interactive user experiences for Web and mobile applications” (Microsoft Silverlight, n.d.).

A games engine called Unity allowed the export of a game to a Web browser via a tool called ‘Unity Web Player’ (Unity Web Player , n.d). At the time of the study, it proved to be an option to get content working inside all the web browsers. There was a limitation to Unity Web Player as the user had to install a three Megabyte plugin, similar to the way flash installs. In a talk by Ralph Hauwert at the ‘Unite 2014 WebGL Deployment in Unity 5’ he talks about Unity Web Player currently having 350 million installs around the world and that number is growing (WebGL Deployment Unity 2014). Once this plugin is installed any further simulations or games using the software will atomically work in a web browser. According to the Unity website the Unity Web Player works on Internet Explorer, Firefox, Chrome, Safari, Opera (Unity Web Player n.d.). At the time of writing, the researcher tested the web browsers with an early working prototype and it proved to work across all the browsers stated by the Unity website. The hardware worked on PC, Laptops, Apple Computer and Tablet ‘Surface Pro’.

4.5 Chapter Summary

This chapter set out to explain the Identification of Statement of Requirements. The researcher felt that due to technical advances in web browser technology it would be possible to deliver a medical health information tool. The target user was identified as non-specialists, in the case of this study asthma sufferers was chosen. The final delivery of the artefact for this study will work through a browser rather than downloading and installing any software products; which is the way ‘Blausen Medical Animations’ and ‘3D4Medical’ works as already discussed in the Literature Review.

There would also be user testing on the artefact to see if it could communicate to a target audience, in this case asthma Sufferers and in a separate study Medical professionals in the form of a Trained Nurse and a Medical Doctor helped validated the artefacts accuracy.

5.0 Realization

This chapter explores the choices in technology to create the 3D web browser artefact. There is a brief overview of how it was constructed and a discussion of the advantages and limitations of the technology. There is also a brief overview of HTML5 and how it affects the future of 3D Web browser technology. Then an explanation of how new areas of technology in film and TV are expanding research and development of real time technologies with new and available software. It explains how learning the basics of programming have helped get this project developed. Forums proved to be a benefit particularly with technology that has anomalies due to legacy issues or bugs that are not explained in a help file or book. It talks about good forum practice to achieve answers to problems that otherwise would have been an unachievable blockage to bypass.

There is an overview of the choices made with regard to the graphic user interface design. It mentions some of the limitations to the 3D visual design working with web browser technology and how it will improve in time. Getting the balance to the information and navigation design and the choices made.

The hardware, software and platform possibilities have been described, how ‘Unity games engine’ and ‘Unity Web Player’ is still the best platform to keep working on until a new solution becomes available.

Also described towards the end of this section is the 3D models creation process, using a technique called photogrammetry. The final section talks about further development of the artefact.

5.1 Why Asthma was Chosen for the Artefact.

There were a number of reasons why the researcher's choice of medical condition in the prototype focused on asthma. The Literature Review talked about a researcher's close family member having asthma. Another reason to create a medical information tool for the public is for the social good it can bring. For example, "There were 1,167 deaths from asthma in the UK in 2011, 18 of these were children aged 14 and under, and an estimated 75% of hospital admissions for asthma are avoidable and as many as 90% of the deaths from asthma are preventable" (Asthma UK, n.d.). This means 1028 asthma related deaths in the UK could have been prevented. According to Crowley;

> "Asthma is the second most common respiratory cause over all ages." And "Childhood asthma is the most common chronic illness, and overall in childhood, accounts for more admissions than any other single condition." (Christopher & Crowley, 2003).

The researcher felt that due to technical advances in web browser technology it may now be possible to communicate with a target audience of asthma sufferers. A prototype was built and then tested on asthma sufferers and medical professionals to explore if the concept of a health information tool could be created, and placed into web browser.

5.2 Reviewing Delivery Technology

Working with technology that has been produced for console development as the vendor's main priority, regular updates can make features such as web development redundant in favor of new working methods. This resulted in the researcher having to download third party plugins to help patch a variety of issues while experimenting with different games engines.

The Unreal Development Kit (UDK) by Epic Studios, showcased a game demonstration that was running through a web browser 'Epic Citadel' (2012) using flash technology.

The website stated it was going to release some website development tools but since then the engine has been in the process of putting emphasis on Unreal 4 and slowly lose support for the older engine. The ‘Epic Citadel’ website is in constant flux with each monthly update from a working prototype to dead hyperlink, Epic Citadel (2012). The Unreal engine deliverables for web browser delivery is in development according to their website, and an active community forum which is currently debating web vendors (Chrome, Firefox and Internet Explorer) are updating their technology which is having harmful effects on web browser development tools. This is mentioned in Chapter 4.4 Delivery Platform, Unity Engineer Jonas Echterhoff talks about web browser vendors being in communication to work out solutions for future development (Echterhoff , 2015).

Figure 44 below shows the results of an earlier prototype made with the Unreal Engine which was made to experiment with their web browser solution and to see how the materials are optimised for online creation. It became evident to the researcher that the Unreal monthly updates added new bugs that broke the interactivity in the game build disrupting the researcher from his goals. The Web browser support from Epic was never fully supported during the researcher’s studies and on forums they admitted to putting development concentration into other areas of the engine. In the games industry the way to bypass update bugs is by having an update lockdown in which the studio decides to no longer update software until a software product is released. The researcher wanted to do this as soon as Unreal released a stable working web browser export but they never did this with the Unreal Engine 3. This meant early on in the researcher’s studies that new games engines had to be explored.

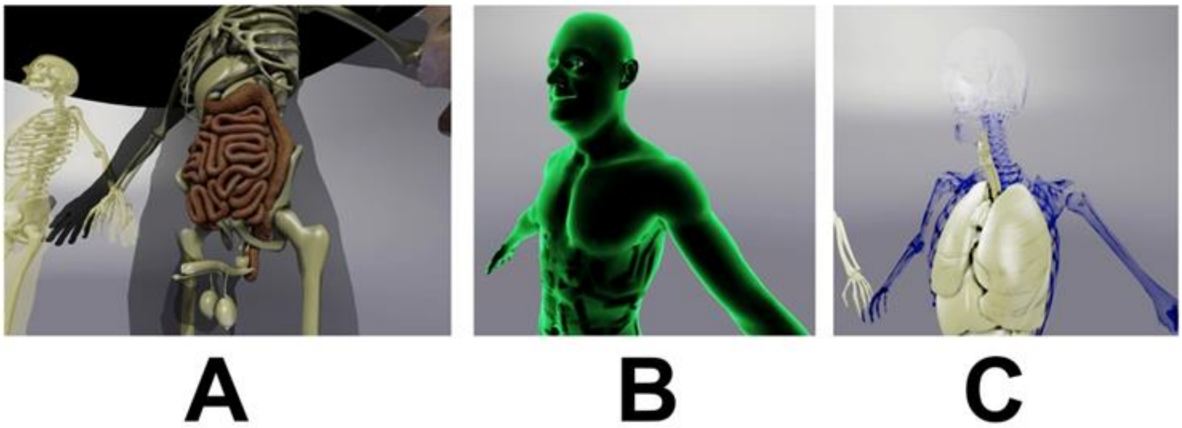

Fig. 33 Gallagher, N. (2013) *Early prototype of the researcher's medical browser*.

In figure 44 it shows the results of what was being produced early on in development. It shows a range of digital surfaces or materials that were customised in the Unreal Engine 3 (UE3). The engine allows for lots of customisable material creations to be produced, it is a sophisticated software product and it was unfortunate the research had to disband this engine. To help explain what the materials are doing, (A) the dark mass was a skin shader that went opaque the closer the camera was to the surface until it became invisible. This saves an artist having to put in lots of animated calculations, it takes some research and development to set up the effect to be produced automatically but if the camera constantly moves in and out of the human body it was worth the development time. (B), the shader was being explored to look like an X-ray using an effect called 'fresnel' and was going to be applied to the bones in combination with (A). (C) was set up to test the appearance of bone structures, again it was controlled with the camera but keeping around 10% of its opacity over the organs to help give the user an indication of where they were in virtual 3D space.

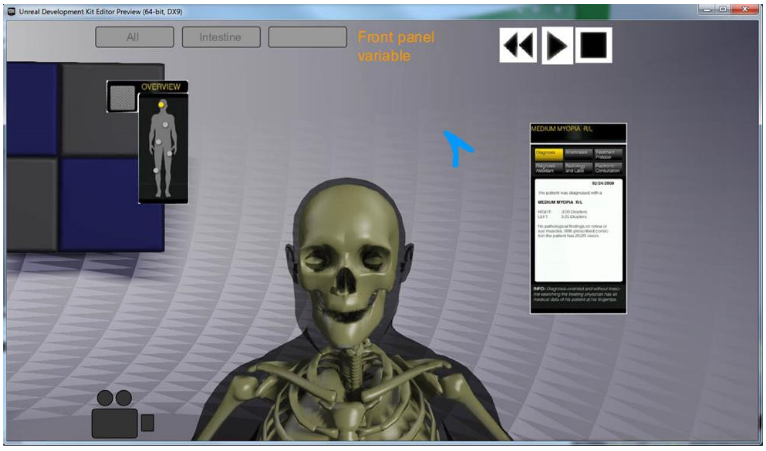

Fig. 34 Gallagher, N. (2013) Screen shot an early prototype.

In Figure 34, the researcher had point and click functionality on organs that triggered a flip-up chart that could tell the user more about the body part selected. These panels could be moved around with the mouse in order to gain a better view of the body. The development tools and material creation by Epic games allow for very quick prototyping but without a stable release and ongoing support of a web browser exporter it would not have allowed for the research questions to be answered so development on the Unreal engine was stopped.

The researcher explored various games engines before making any choices on a final development path. The ‘Cry Engine’, ‘Havok Vision Engine’, ‘ShiVa’, ‘HeroEngine’ where all versatile games engines. ‘Havok’ suited physics, ‘ShiVa’ & ‘HeroEngine’ was a good cross platform engine, good for game design and the ‘Cry Engine’ had clear and sharp graphics fidelity with good lighting. The problem with these engines was the online help guide was very limited and much of the time incorrect or had defunct information. These engines might be good for their own in house company development with technical team support. For the researcher, unless they put more emphasis on online documentation or video tutorial content the learning curve proved to be very hard, the communication response from the companies when the researcher emailed was that the online help documentation was in development and will be updated in time. These engines also promised web browser support in future developments or in totally new versions of their engines but at the time of writing this study there was not any web browser support so the researcher carried on in search of a new Engine.

5.2.1 Choice of Games Engine, Unity

In the Literature Review the researcher reviewed how the ‘Unity Web Player’ functions by testing some simulation and games, see Chapter 2.5 ‘Interactivity and Simulation Software’ for further details.

The results of the simulation and games proved to be working with a good frame rate and reasonable quality graphics. The games that were working inside a web browser contained animation, interactivity, audio and lighting, which were all features that were needed for the researcher’s artefact. According to Hauwert at the ‘Unite 2014 WebGL Conference’ there had been 350 million installs around the world of the Unity Web Player and that number was growing (Ralph Hauwert 2014). When a user comes across the Unity Web Player while browsing on the internet, they are presented with a one off install of a three megabyte plugin that installs with a simple click and install option, it is the same process as flash and Java. The researcher reviewed the cost of the Unity Engine, a professional license was available at $1500 which gives access to extra graphical features such as Shadows, Customizable Splash Screen, Post Process Effects. There is a cost free install option that does not have these options but these features work best as a standalone executable game for PC’s and the console market. The reason is due to the user being able to adjust the resolution and other graphic options to suit their hardware platform or a developer can preset them for the console market to get the best performance for a particular hardware platform, Nintendo, Sony, Xbox. As these features were not available for the ‘Unity Web

Player' it did not affect the researcher's final artefact so the free option was a good match for the requirements of the project.

5.1.2 Unity, Learning Resources

The download and install process of the Unity engine is a process of downloading an executable from the Unity website and going through the install process. A login is required and once logged in it opens an empty scene ready for importing content from a third party 3D modelling software such as Maya or 3DSmax.

In order to get started with creating content for the Unity Games Engine lots of learning resources had to be reviewed in the form of websites, books and forums. The first option was to read some books, 'Unity 3.X Game Development Essentials' and 'Unity Game Development in 24 Hours' both provided the researcher with solid foundation in Unity's software development tools. 'Unity 3.X Game Development Essentials' was a good book for starting in the Unity engine. The author is Will Goldstone who works for Unity Technologies as a technical support. The book is aimed at teaching the Unity with no prior knowledge of the software being needed. It also taught two programming languages, C# and JavaScript with a step by step approach. The second book, 'Unity Game Development in 24 Hours' was created by Mike Geig, who works for Unity as a trainer and his focus is software engineering. The book was geared towards the creation of a single game broken down in a series of tutorials that were made to take around one hour each.

Once the researcher went through the exercises in both books many of the lessons were reversed engineered to be used in a simulation scenario rather than a game approach to enable the creation of the artefact. As an example, object selection in the artefact was made with Ray Fire, which is a common software approach in a game for setting up a gun in games like first person shooters. It works by firing a ray or beam from the center of the camera view point onto where the mouse cursor is aimed and hitting a virtual collision box which a developer attaches to a character, vehicle, object or button. If the Ray Fire does not collide with anything then nothing happens. It was this process that was used for the trachea browser section of the simulation. The researcher attached collusion boxes to the organs around the Trachea and when triggered a cinematic accompanied with audio. There where issues such as 3D audio going up and down in volume as the camera moved to and from the source in 3D space. When the researcher came across these kinds of issues and could not find a solution a useful resource to go was on community forums and find out how to create flat audio for example which proved to be scripting the audio to be an announcement audio file.

Unity Games Engine is similar to Unreal in the fact that the software tends be updated every month or two and both books missed the Unity 4.0 release. This meant lots of functionality was defunct, missing in Unity menus or the update created legacy issues. The researcher decided to stay with version Unity 3.5.7 which was the most recent update before changing to Unity 4.0 and through the duration of the research the researcher locked down the software which is a common practice in the games industry and an update will only take place once a game is released, then retaining the work force can take place. In the case of this study the software was locked down until the artefact was submitted. This has allowed the researcher to review some update practices to be implemented for future development of the artefact. This is covered in Chapter 5.12 ‘Further Development’.

Once the essentials are covered through books, internet tutorials such as ‘Digital Tutors’ (2015) proved to be an informative resource for specific development details such as optimising the skinning on rigging inside a 3D software package such as Maya. By learning and building up development shortcuts such as rigging and animation (as it becomes automatically optimised upon exporting to a game engine) can save developers a lot of development time as a games artist can bypass processes rather than laboring over them. It is good practice to test pipelines with games engine updates, as many of them are not updated on the company’s online help file and will remain a legacy issue until resolved. A digital artist can build up this knowledge rather than performing one pipeline aspect at a time only to realise the work has been stripped through the export process. This is why it is important to share knowledge with the online community through forums and websites as it benefits all developers.

Unity have their own active community forum. If an answer to a problem was not obtained from the company’s own forum then artist forums such as Polycount (2015) and Game-artist (2015) proved to be a useful resource to problems such as animation, camera movement, polygon counts, optimisation and other best working practices. Answers are normally responded to by industry professionals who may have a team working on the same issues as an independent developer.

Early tests of the artefact proved to run at a high frame rate of around one hundred frames per second (FPS) on the researcher’s laptop which is a high end laptop ‘Alienware M17x addition’ 2013. In order to test the artefact could run on a reasonably average laptop £350 laptop (10/01/14) two where hired from a loan store at the University of Hertfordshire and around thirty to forty FPS was achived and it never dropped below thirty FPS. The Unity website has a detailed web player hardware statistics page should a user want detailed information on a particular hardware component or operating system ‘Unity Web Player hardware statistics’ (Unity Hardware Statistics 2015). When the researcher had learnt and tested the Unity engine to prove the pipeline could perform the research questions it gave the researcher confidence that the Unity Engine was an appropriate choice of development tool.

5.2.2 Key Factors, Unity Web Player

A key factor in answering the research question, the choice of the games engine had to be able to produce a 3D medical visualisation system that works through a web browser. The Unity Games Engine has an export function called Unity Web Player. According to their website 'The Unity Web Player enables you to view 3D content created with Unity directly in a browser and autoupdates as necessary.' (Unity 2014).

Unity Web Player development tool allows for communication across all common web browsers. In order to get the artefact running, a website needed to be created. A subdomain of a forum the researcher currently runs was created and this allowed for live web support from Host Gator when bugs or issues happened.

One of the limitations with using web browser technology is that developers are outside the parameters of the Unity engine, which means there is not any debugging software. When a developer finds bugs and legacy issues there are not many avenues for help, outside of contacting the developer and using internet forums. If this does not resolve an issue then the user has to roll back the script and try a different method, possibly a patch or a plugin, which can either resolve the issues or compound a problem. It was good working practice to back up regularly and also compile code regularly. This process would allow the researcher to obtain a better guesstimate of where an issue might arise from and roll back if needed.

In the games industry software such as Alienbrain Asset Management (2014) and Shotgun Software (2014) are both production tracking software. It works by a team member, designer, programmer, artist, musician has a working feature they can check it into the overall game, it can then be rolled back to a working example should anything break or cause a bug to the software. As the researcher was not working in a team it was possible to use Google Drive (2012) as it has a history revision.

5.2.3 Cross-Browser Support for 3D

Currently the process for 3D Web Technology is complicated, in regards to 3D web browser creation;

> "It's the sort of thing that comes with the web application development territory. Cross-browser support has always been notoriously difficult" (Parisi, 2014: 1).

To help give a brief overview of how the website and Unity Web Player was created and exported here is a brief explanation of the process. The researcher started by creating some content in Unity to be able to test the export to web browser pipeline.

For the export process a file named 'Unity Web Player plugin. HTML' is the file hosted inside a website domain, it contains some 'MonoManager ReloadAssembly inputs' that have some call functions and they are manually scripted using JavaScript inside the browser. To help with the set up process there is a twelve page Web Player Deployment document on the Unity website (Unity Documentation 2014). Posting on community forums can help independent developers with this process as there can be lots of blockages due to unforeseen issues such as legacy issues, bugs in the software or simple debug instances such as a adding some simple code like 'Configuration Manager.Refresh' which will force a re-read of a flagged section of code. Reading on forums a 'Refresh' can cause issues, loops in the code so it is to be used with caution and this was created due to a limitation of the researcher's abilities. In games development it is best to work in a team with specialised skill, as a good programmer can compact code to run more efficiently and allow for faster loads. At the time of writing this study, JavaScript had to be used to obtain a reference to a Unity Web Player export inside a hosted website. This was one of the reasons why an application had to be used to launch Unity Web Player in a web browser. Once it was installed a user could access any website using Unity Web Player to run games and simulations.

Modern day console games tend not to have load screens due to seamless content loading in real time in the game. This is produced by ‘Streaming Assets’ and was achieved with the artefact to help speed up the online version. It was achieved by creating four clones of the digital human, known as ‘Object Instantiate’. As they are the same model it is very low impact on memory but with the advantage of being able to apply a different material customisation. As the camera changes location it cuts out the other digital models from memory. This is known as ‘cullingMask’. Before the camera cuts to the next digital human it loads up ready for the camera. This had to be produced as Unity could not support material changes and transparent materials cause visual anomalies so unique models with unique materials had to be created. It was good practice to go to the Unity Web Documentation for this and many more issues in the creation of a simulation artefact as every game engine have unique ways of doing similar operations (Unity Shader Lab: Culling & Depth Testing 2015). Due to the complexity of games development there are areas of development where the researcher was stretched in development skill due to working independently. This was a conscious choice as the researcher wanted to develop their technical abilities and expand new range of skills and abilities. As regards to;

> “meaningful learning, interesting learning and a state where the individual has the drive to learn, that state which motivates the individual to get to the bottom of what is happening in a situation – the state of discovery, enlightenment and development.” (Karen, 2010: 9-10).

It is possible that more refinement of pipeline efficiencies could have been implemented but this is true of most software development projects and why regular updates are released, such internet explorer being at version 11 at the time of writing.

5.3 HTML 5 The Future for 3D Web

Hypertext Markup Language is currently in its fifth development cycle and which is given the name HTML5. It is currently in development by the World Wide Web Consortium (W3) and is overseen by *'Sir Tim Berners-Lee'* the inventor of the internet (W3, 2014). What Hypertext Markup Language allows is web browsers to read HTML so users of the internet can view and search for content in a web browser due to the nature of its construction. HTML5 allows for many new features. This chapter will focus on why it is important in relation to the researcher's artefact as HTML5 allows for 3D content to work in a web browser without the need for any plugins. According to Parisi;

> "With HTML5, the web browser has become a platform capable of running sophisticated applications that rival native code in features and performance. HTML5 represents a massive overhaul to the HTML standard, including syntax cleanups, new JavaScript language features and application programming interfaces (APIs), mobile capabilities, and breakthrough multimedia support" (Parisi, 2014: 1)

The latest version of HTML5 is made up of three types of scripting languages known as 'Web Graphics Library' (WebGL), 'Cascading Style Sheets' (CSS3) and 'The Canvas Element' (Parisi, 2014: 1). 'WebGL' is now standard on most web browsers apart from Microsoft Internet Explorer which has their own solution for developers to create 3D called (Silverlight 2013). On the Microsoft website it mentions Internet Explorer 11 will allow WebGL to work on their browser (Microsoft WebGL 2014). 'CSS3' Cascading Style Sheets language allows for hardware-accelerated 3D & 2D rendering, that will allow for 2D flexible grid layouts that can layer up over each other and for 3D content it allows for graphical improvements such as shadows and 3D transformations which is useful for animation. 'The Canvas Element' is JavaScript that allows browsers to draw 3D objects to the 'Document Object Model' (DOM) by interacting with the web page, transition data between points in space and allowing for animation content to be viewed (Parisi, 2014: 1).

HTML5 is an exciting direction for web browser technology as it will work on a range of hardware products;

> "3D processing hardware is now shipped in every computer and mobile device, with the consumer smartphone of today possessing more graphics power than the professional workstation of 15 years ago. More importantly, the software required to render 3D is now not only universally accessible, it's also free. It's called a web browser. (Parisi, 2014: 1)

This will mean when the researcher's artefact does work through native HTML5 the artefact will work globally to a much wider audience;

> "Worldwide, we see a number of health issues that are directly and indirectly related to communication. Global issues such as the lack of access to adequate Healthcare, war, poverty, hunger, environmental justice, and lack of education about health issues continue to pose problems for people around the world. Unfortunately, many of these issues have had the greatest impact in undeveloped countries and among the underserved populations. In Africa, for example, over nearly 25 million people are living with HIV/AIDS, 2004". (Wright et al, 2007:5)

By having a Web Browser experience on various devices including mobile phone platforms will open the outreach to the researcher's artefact to a much larger audience than what 'Unity Web Player' can offer. This will allow the possibility of directly affecting health communication for everyone that has accesses to a web browser and most current devices of today.

5.4 Accessible and Available Technology

Creating a 3D games engine from scratch is a very extensive and costly process. When the researcher worked for Microsoft and Nintendo there where teams of programmers and designers that worked globally across different studios in order to create a new games engine. With each generation of games console development the process of creating a new engine would start again. The engines were custom built to best suit the needs of a games market area. It is still an ongoing tradition for many developers today with many of the in house proprietary engines tailoring their games engines to best suit the creator's needs.

The solution to bypass the issue creating a games engine is to download one. For example the Unreal Development Kit (UDK) game engine is free. The professional addition is $99 for commercial license and then the developer is required to pay a royalty fee of 25% once $50,000 of capital has been made. This is obviously an attractive offer for small independent developers. The Unity Engine, which was used to create the researcher's artefact is currently free for education and has a fee of $75 per month for a professional license if the project was to become commercial.

For the creation of this artefact the researcher will stay with the Unity games engine.

When a games engine is released with a functioning export that makes use of a HTML5 to a web browser the researcher will evaluate the new tools.

5.5 Advances in Current Real Time Rendering in Games

Real-time rendering has improved dramatically in recent years. According to Moller;

> "In the past few years advances in graphics hardware have fueled an explosion of research in the field of interactive computer graphics"
> (T.A.Moller, 2014: 2)

As hardware becomes more powerful, polygon limits have risen in the amount a processor can compute per frame. Traditionally a rate of twenty-five frames per second (FPS) is the standard but that is now being pushed to 48-60 (FPS) on the current generation of consoles (Xbox One and Sony PlayStation Four) and on PC it can reach 80FPS at 4K (4K = 4096 × 2160 pixels) on many modern games. Polygon limits are the amount of computerised flat cards a computer has to draw to make an object. The higher the number, the less blocky the object and more importantly the more refined its silhouette can become.

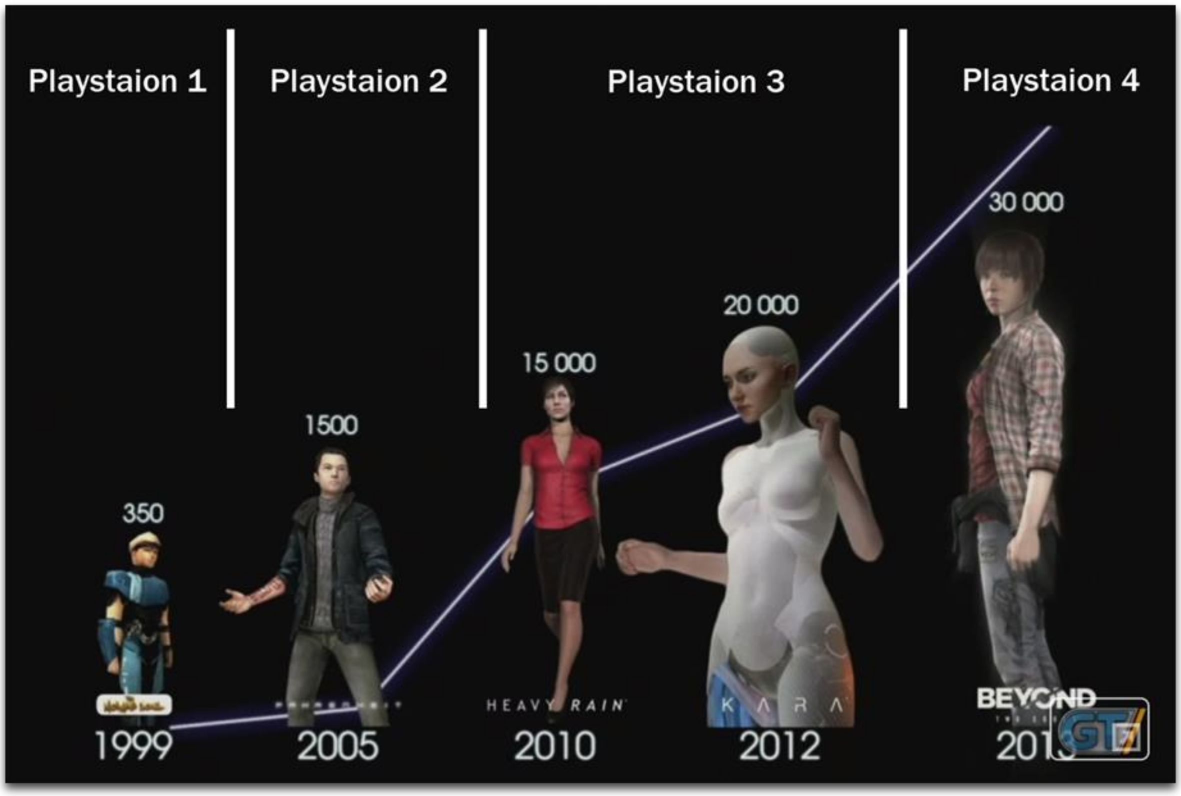

Fig. 35, *Sony PlayStation 4 Reveal, New York Showcase* (2013) uk.playstation.com

With the release of each new console there is a rapid rise in polycount (the number above the characters heads in figure 35 marks the number of polygons used to make each model). Compared to the rest of the characters in figure 35, the polycount on the PlayStation four manages extra details such as crumpled clothing and the addition of transparent lengths of polygonal hair, which all helps add interesting silhouettes and detail to the character.

An issue with real time rendering (RTR) is maintaining a stable frame rate. It would be detrimental to make a medical web browser artefact that had high polygon definition graphics and as a result the simulation only rendering at five FPS and taking forty seconds to load a simulation. In the industry, developers call slow frame rate “lagging”. It is a measurement that games companies currently measure in milliseconds (MS) and anything under 40ms per frame needs adjustment to make it faster. Games engine development kits come with a FPS counter but it is always best to work in ‘ms per frame’ as it is more accurate to get an average as it can show where exactly there might be any problems.

Last generation consoles - 1000ms/sec / 25FPS = 40.0.. ms per frame

Current generation consoles - 1000ms/sec / 60FPS = 16.666.. ms per frame

With PC software products it is hard to tailor a product to suit the need for the vast range hardware and this is why developers add a “Graphics Menu” inside a PC game or product to suit the need of its end user. Currently this is not possible with Unity Web Player as the graphics output is set upon the export from Unity, version 3.5.1. With each upgrade of Unity better graphics settings becomes available for the developer.

Many real time features that mimic rendering are starting to appear in games engines such as ‘Global Illumination’ which is constantly being researched into by Epic with their engine Unreal 4 (UE4 global illumination 2015). As computers get better hardware components, real time rendering will only become better, especially with regards to the graphics processor units (GPU) which directly affect real time rendering capabilities. All this hardware allows for real time functions such as post process effects that can be layered on top of 3D geometry to make the real time image presentation replicate real life and camera anomalies. There are many functions available when applying post process effects which allow artists and designers to tweak the overall look and feel of a scene.

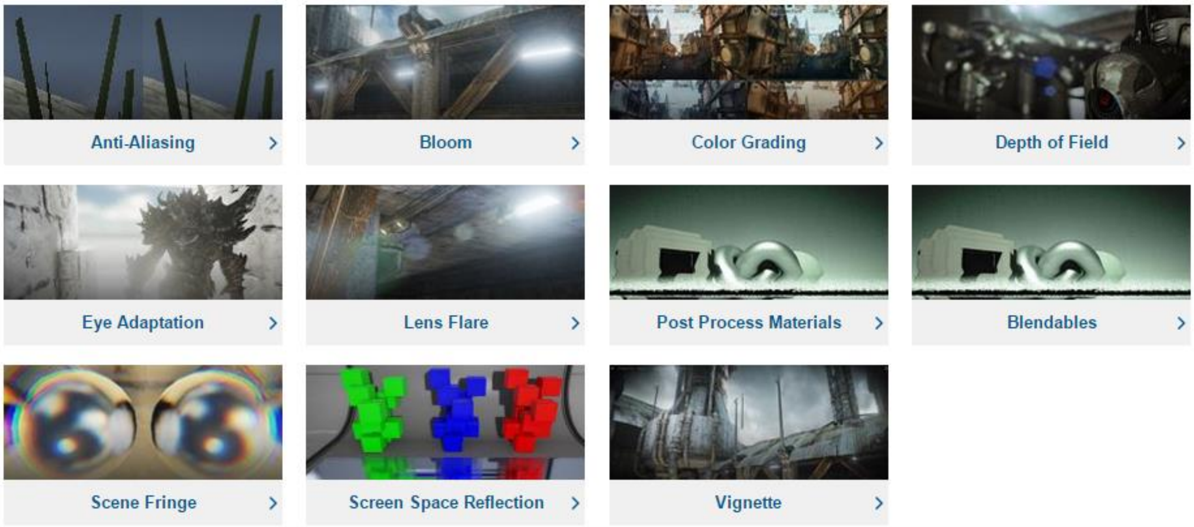

Fig. 36 *Unreal Post Process Settings* (2015) docs.unrealengine.com

The researcher tried to apply post process effects to the medical artefact in Unity. While it was possible to apply them it damaged the frame rate on low end PCs to less than 10 FPS due to it absorbing all the processor power on the Web Browser experience. Asking about it on forums the technicians at Unity said they have allowed the feature on the professional version of Unity for console development but need to do further optimisations for the online version.

A real time engine called Marmoset, according to their website; “Marmoset is a powerful, standalone real-time renderer bundled in a tidy package. GPU-powered. Physically accurate” (Marmoset n.d.).

Fig. 37 Marmoset, Artist Glacuco Longhi, (2015) marmoset.co

It is clear from figure 37 that Marmoset engine can achieve a high clarity digital human model. The engine's purpose is to deliver a still image of a model for a 3D artists portfolio. What it shows is the potential level of clarity a real time engine can produce on a PC.

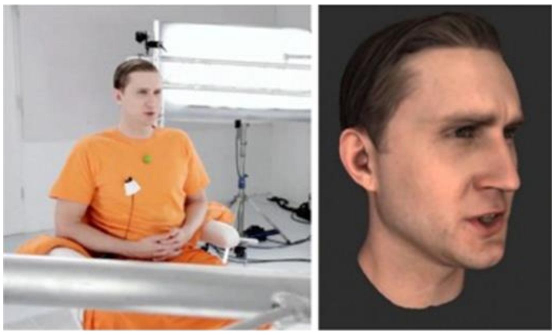

Fig. 38 *La Noire* (2012)
rockstargames.com

Fig. 39 *NBA* (2013)
EASports.com

Real time imaging of human representation in figures 38 and 39 shows the progress that computer games engines (Xbox 360, Nintendo Wii U & Play Station 3) have made up to the generation of games consoles. It shows how far developers pushed the hardware to the peak of performance without having to drop in frame rate. They show how far virtual representation of the human form has improved and this is without the use of higher-level shader language and high definition resolution that the current generation game consoles offer.

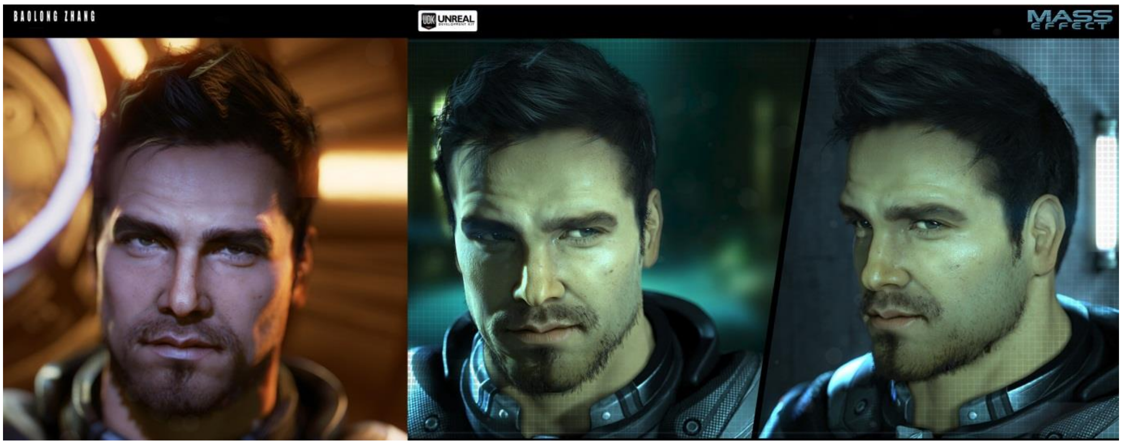

Fig. 40, *Bioware Challenge, Mass Effect* (2013) polycount.com

Baolong Zhang is a Lead Character Artist at Supermassive Games Ltd and he produced the 3D digital character in Figure 40 on a last generation engine, UDK. This engine was built to serve the (Playstation 3, Wii U and Xbox360) era. The techniques are only possible with DirectX 11 turned on it is not possible to publish a game with this feature turned on in (Playstation 3, Wii U and Xbox360) and web browsers. Epic Games studio released DirectX 11 tools to allow artists to experiment and see what difference it makes to their 3D scenes shortly before launching the Unreal 4 engine which will have these features set on by default. As can be seen, Figure 40 it is an example of what DirectX 11 in UDK allows with features such as anti-aliasing, which enables single hair strands to be produced. Vector transforms helps spread out clumps of hair evenly and polygon hair strands can spread out dependent of the camera angle so it no longer looks like flat polygon cards. Subsurface scattering material for the skin, advanced lighting and soft shadow fall off with high dynamic range imaging (HDRi). These are just a few of the techniques Baolong Zhang used to create this image according to his Polycount forum posts (2013, Zhang).

As the new generation of games consoles come out (Playstation 4 & Xbox One) it will push graphics fidelity to much higher level of clarity.

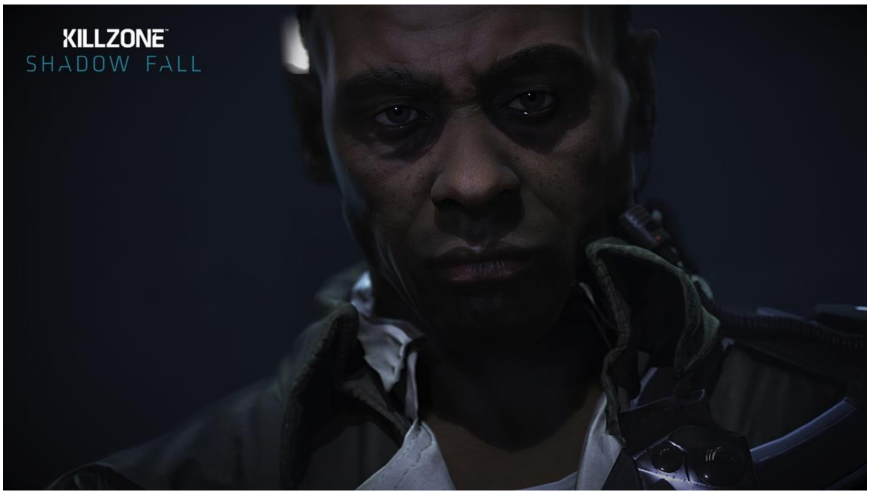

Fig. 41 *Guerrilla Games Studio, Killzone* (2013) guerrilla-games.com

There are a number of reasons why the character in figure 41 is an improvement on the last generation of games consoles. Michal Valient, who is a Lead Technical at Guerrial Games Studio, wrote a postmortem technical paper on the games construction for the Playstation 4 (2013) Guerrial Games, Killzone, Shadow Fall document, released on their website. To summarize the document the biggest improvements were down to having four times the resolution, better calculated materials, a physically correct lighting model, properly calculated geometry with attenuation factors, all materials supported translucency and Fresnel effects and the lighting is all based on area lights.

To help showcase PlayStation 4 (PS4) capabilities, Quantic Dream were commissioned to produce a technical demonstration featuring an old man running on a (PS4).

Fig. 42 *Quantic Dream* (2012) quanticdream.com

Quantic Dream was able to produce advanced skin shader technology using skin translucency, realistic ice materials, volumetric lights, and 3D depth of field, *Quantic Dream* (2012). The wrinkly face allows for small details captured in high resolution -2K, highlights, shadows and bumps that have been created in a 3D sculpting package such as ZBrush by Pixologic. There is subtle subsurface scattering in the skin on the frown line, and neck and ear, best seen on the figure far right.

The current generation of games consoles dictate the features that are available in games engines due to the supply and demand for its vendors, who are traditionally games studios and independent games developers. The technology then filters down into mobile, tablet and web browser technologies. To push real time content in new directions such as simulations, architectural visualization and automotive then independent developers (also known as 'modders') can tap into these high risk areas, as cooperation's may not show interest in an area until there is a safe established market. According to Kücklich;

> "Without the creativity of modders, developers would be hard-pressed to come up with new ideas, and it would prove hard to implement these ideas in the high-risk gaming market were it not for the huge "test-market" the modding community provides". (Kücklich 2005:1)

If the market for real time technology was to expand into other market areas such as simulation, virtual reality, architectural visualisation and particularly film and television industries, then that would have an effect on the research and development of real time games engine technology. The next chapter looks into new market areas directly relating to real time technology.

5.5.1 Real Time Rendering Development in the Film and TV Industry

New technologies that have recently come onto the market are real time rendering software, Digimania (Digimania 2015) and Autodesk Stingray (Stingray 2015). Callum Welsh said in his email (see chapter 2.5.1) “real time graphics technology may even replace rendering medical animations altogether”. It may be possible that these kinds of products are the ones to replace rendering. To expand on this point, Digimania is using Epic's Unreal Engine to render data in real time straight from data sent from 3D modelling packages such as Maya or Max at 4K output (Digimania 2014).

Fig.43 RenderDigimania Promo Nov 2014 - Siggraph Asia (2015) digimania.com

As can be seen in figure 43 the output has been produced to a high quality. While it will be missing some features that are only achievable to a high degree of clarity with rasterized rendering such as true ray-tracing, global illumination and refraction, there are many projects that might suit faster output compared to the cost and time of rendering.

Another real time render is Stingray, which is made by Autodesk who make 3ds Max, Maya, and Maya LT software so it is integrated inside those products as they are the main 3D packages uses in the film and Games industries by 3D Artists. According to Autodesk Stingray (2015) website;

> "Whether you're a developer creating 3D games or a design professional creating real-time visualizations, the Stingray engine helps you produce visually stunning 3D experiences. (Stingray 2015).

To help explain the length of rendering compared to real time graphics 'Pixar' is a company that has lots of experience in this area due to every frame in their films being purely rasterized rendered computer graphic images. According to Terdiman;

> "One of the keys to Pixar's ability to do what it does is the giant, powerful render farm located in its main headquarters building here. This is serious computing power, and on '*Cars 2*,' it required an average of 11.5 hours to render each frame". (Terdiman, D. 2011)

That means per second of footage for *Cars 2* at the cinema, which is classed at 24P meaning 24 FPS it would have taken 276 hours. As Cars 2 is two hours long the calculation for the average render time for the film is as follows.

24P X 11.5 hours = (276 hours)/ 276 hours X 120 minutes = (33120 hours)/ 33120 hours converted into days = (1380 days)/ 1380 days into years = (3.7 years)

If Pixar where able to render in real time it would obviously cut production time down dramatically. At the GPU Technology Conference Pixar's engineering lead Dirk Van Gelder Gavea gave a key note speech about a real time proprietary animation system. Pixar have called the real time engine Presto which started development in the Pixar film Brave and was used in development in Monsters University (Pixar Presto Demonstration 2014).

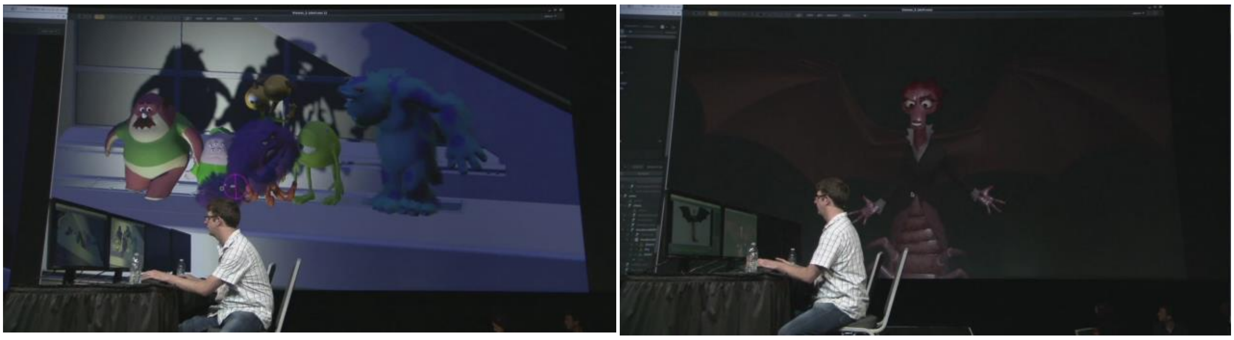

Figure 44, GPU Technology Conference (2015) gputechconf.com

Pixars's real time Presto engine has similarities to rendered footage as Pixar films are purely CGI rasterization rendering. The Presto engine has the same ethos to real time imagery, which is a 3D image made from purely 3D graphics.

For the visual effects industry, it has a different set of problems; films tend to have live action filmmaking with computer generated 3D models blending into the footage. To completely replace every element that makes up film footage is a much harder process to mimic, as all of the footage has to look as close to reality as possible. However there is a visual effects short film called 'Construct', it is an example of real time rendering being used to produce a visual effects film. It was rendered entirely on GPUs and was made for a tech demo at Nvidia's GTC conference. According to Mufson;

> "The results capture the beauty of ray tracing in real time, allowing for the kinds of creative decision making that had, until now, only been possible with rasterization or live action filmmaking. It's a killer combo that could open digital storytelling up for both independent filmmakers and studios, alike." B. Mufson (2015).

Fig 45, Construct (2015) constructfilm.com

The Director of Construct is Kevin Margo and he is the VFX/CG Supervisor at Blur Studio and this company work on Hollywood Films, TV commercials and Game Cinematics. Companies like Blur Studios have an understanding of games and film rendering disciplines, their portfolio ranges from game trailers to film and television.

Another person who works in film and games as a motion capture artist is Andy Serkis. He also founded *'The Imaginarium'* studio and according to Andy Serkis;

> "There was probably a time when people in the games industry wanted to emulate films, but now it's very much the other way around: the technology is driven by video games. So, for instance, virtual production, pre-vis, many of the tools we use in the film industry have come out of the games industry" (Steve Boxer 2013).

Andy Serkis mentions virtual production which allows film directors to have access to real time games engine tools to help visualise their pre-visualisation to large visual effects teams. It is this collaboration of technology between the film and games industries merging that will allow for better tools in both disciplines.

In a key note speech at BAFTA in London, Kim Libreri, chief technology strategy officer at Lucus Films, Bell said;

> "Over the next decade video game engines will be used in film-making, with the two disciplines combining to eliminate the movie post-production process" (Bell 2013).

Now the film industry have real time technology as part of their pipeline it will drive vendors and independent developers to produce more research and development software tools. This will allow development to happen outside of the current supply and demand that comes with the current console development. These products are new to the market such as Digimania (Digimania 2015) and Autodesk Stingray (Stingray 2015), and have only come onto the market at the end of summer 2015.

5.6 Scripting in C # and JavaScript

Due to the researcher coming from a 3D Artist background there was an appreciation of the benefits to scripting in 'Mel and Python', a common language used in Maya which is a 3D modeling package commonly used in the games and film industry.

The job of a technical artist in the games and film industries is primarily to speed up production by solving problems and creating new development tools. Their knowledge of console hardware architecture would help them communicate the future direction of a software artefact and act as a bridge between the artists and programmers. They would anticipate the future direction of a software product and produce software tools and plugins to speed up production workflows and pipelines (Skillset Technical Artist 2015).

For this study there was an opportunity for lots of new technical software learning in order to create the artefact and gain a better understanding of the role of a technical artist.

A large part of the research in the creation of the artefact was to learn the basics of (C#) and JavaScript which are both programming languages. These programmes were learnt for two reasons. C# enabled the control of 3D graphics and the user interface (GUI) inside Unity, it enabled the games engine to give and receive commands and drive content in the simulation to become interactive. JavaScript helped with the creation of the Web Browser in order to set up and embed the Unity Web Player executable which was loaded on the website. Unity also allows for JavaScipt to power the 2D elements.

By learning the basics of (C#) and JavaScipt it allowed the researcher to understand the basic functions and notice when command prompts, parameters and functions came up with errors and was able to debug the issues with the limited knowledge picked up from books and tutorials.

The process of learning (C#) was mainly reading tutorials in two books in particular, 'Javascript for Dummies' and 'C# for Dummies', watching YouTube tutorials and Digital Tutors videos, posting on forums and looking through threads with the same issues. The 'Help' menu in the Unity games engine hyperlinked to the game engines website 'The Unity Scripting Reference' which was kept up to date on many issues apart from the Unity Web Player which needed updating.

When the researcher started programming the artefact, a basic outline of a script would be written. Then the researcher customised various components until the functionality give the required results. Towards the end of the project the researcher had a data bank of useful code formed into small bunches of script. By giving it a title it could be searched for and copied and pasted into areas that needed the same or similar function. When errors happened the researcher would try to fix the issue and if it could not be resolved it would be flagged and commented out and the researcher would come back to it later after some further research.

To fix many of the errors in the code it was useful to compare and contrast the script to old lines of code, this process fixed many of the bugs. Normally there was a bracket or comma in the wrong place or an incorrect comment like a variable with the wrong calculation. Formulating good working practice was important, for example testing the code regularly rather than adding too many script components at a time and then having to debug more than one problem at a time.

When the researcher worked for Microsoft Games Studio (Rare) the programmers used a programme called ‘Visual Studio Ultimate’ (MicrosoftStore, 2013). It would package their C++ programming code into tidy packages and would be managed across the team by the lead programmer who could configure the overall game engine. The development tools for ‘Visual Studio Ultimate’ cost £13,482 per license. There was a cheaper and node based solution to help with the many scripts that were becoming unmanageable to debug, which was due to searching through a tall vertical page of script to iron out problems. The solution to the problem was a software package was called ‘Playmaker’ (Figure 61.0 below). Alex Chouls and Erin Ko formed ‘Hutong games’ and were working on a solution for Unity to help artists keep control of scripts in a manageable way. Playmaker is a visual scripting tool that allows users to write custom actions within a node and plug them into other nodes once the function has finished. Figure 61.0 below is a screenshot of part of the flow chart. Each node contains script function that drives the medical simulation.

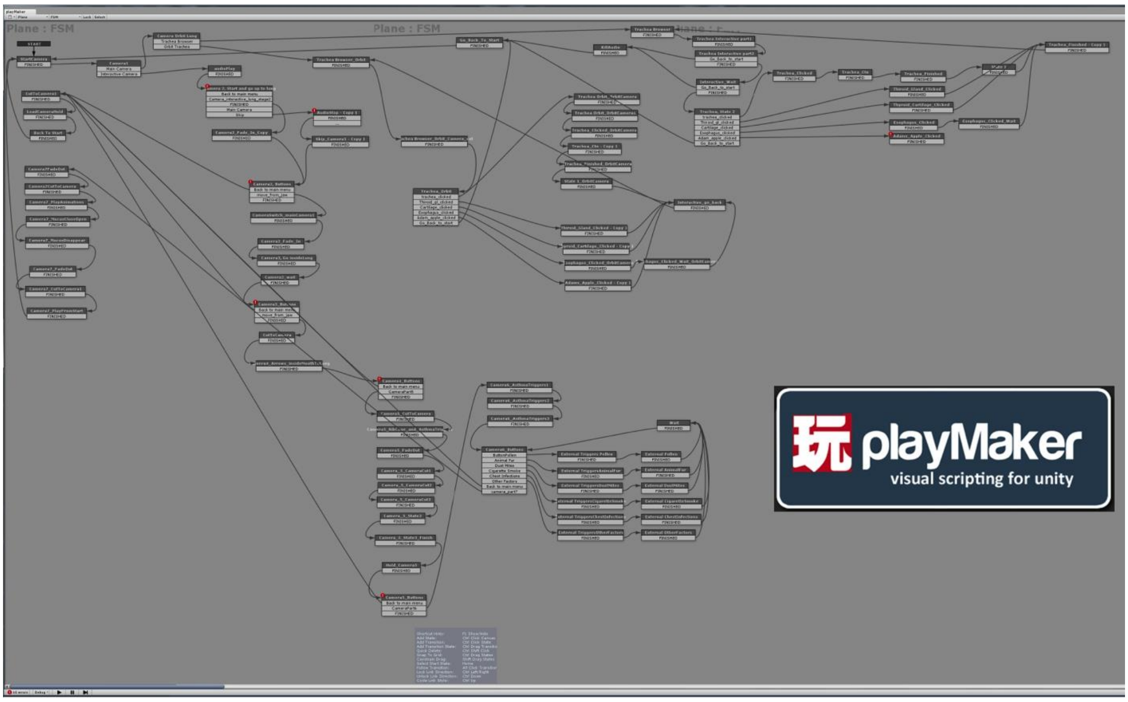

Fig. 46, Gallagher. N, Hutong Games "Playmaker" (2013)

Each node in figure 46 could contain script commands. Once the node is selected through a command prompt such as a mouse click it would pull up call functions such as play and stop audio, move the camera, trigger events such as making materials go from solid to opaque. The researcher would try to make all of the visual and audio user interactions work seamlessly together before the next sequence started. Before coming across 'Playmaker' the script for the GUI was in a long list and matching up with the written dialog with the buttons caused lots of miscommunication bugs between the user and the simulation. Being able to place the script into a visual node helped clean up the interactivity.

The following figure 47, was an example of the code that went into the many Playmaker nodes. In this particular case the JavaScript can be seen on the right and drives the camera orbit and selection process. On the left is the (C#) Assembly UnityScript which is ready for an input. In this case clicking the mouse when this node is activated would trigger a process called Raycasting. This allows the user to select polygonal objects by firing a ray from the center of the camera to where the mouse is looking and hit a collision object. In this case it was an invisible 3D object placed in exactly the same place as the higher resolution organs around the trachea and the trachea itself. The 'Raycast' function gets called into an 'IF Statement' and if it returns true, or in this case if the 'Raycast' hits a collider then it commands the 'IF Statement' to be carried out. Once an organ is hit with a 'Raycast' it would trigger a new node and the process would start again.

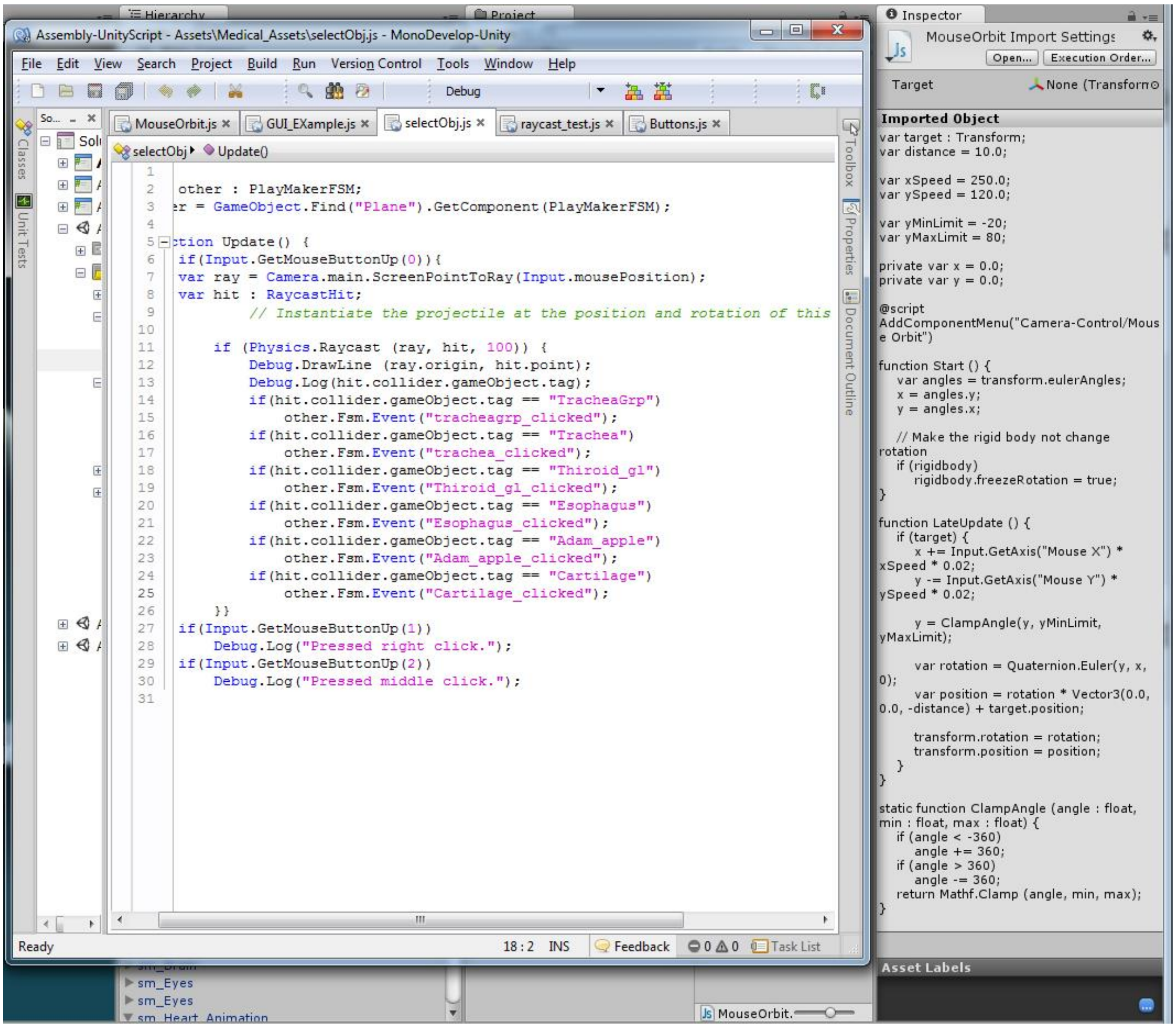

Fig. 47, Gallagher. N (2013) *Unity Scripting*

The artefact was presented in a website and JavaScript was used in its creation. Unity Web Player is able to communicate with HTML and the commincation works both ways. When the web page is opened it calls the functions for the Unity Web Player to start.

Once the plugin is activated it works across all internet pages that have UnityWeb Player. Another aspect of having the artefact presented in a web browser was that HTML can link text related to the ailment, for example by searching for the words wheezing, coughing and breathlessness then ‘asthma’ comes up as a possible option. The key words written within the synopsis of the condition can be linked to the search bar, this function was tested and works on the researcher’s website.

5.7 Using Community Forums to get Solutions

Community forums provided a reliable source to solve many blockages. Many software issues cannot be answered in a book or manual, for example due to a bug or legacy issue. To help resolve many software issues it was good practice to post problems, questions and answers on community forums. This enables technical issues to be resolved due to people coming together as an online community and resolving software problems. Games engine technicians are active on community forums, so an answer to a problem can happen rapidly, especially when posted on a company’s own forum. The reason is mutually beneficial to both developer and company, the company gets to fix a bug and the developer fixes their problem.

In order to get results from the forum the researcher found a few etiquette rules helped. For example sharing research information with the community and answering other people’s problems. Being polite, especially as coders who are new to a subject can ask what may seem like a basic question to a midlevel to expert programmer, as so some comments in the forum thread can appear to be condescending. When these comments arise being polite and posting another updated version of script shows the community the researcher is trying and it can have a positive effect on a forum thread as answers start to appear. If the researcher had posted the same question on another forum then sharing the answers is good for the community. If an answer with a better approach to a script has been posted then again it is good practice to share and credit with a hyperlink to the various communities. It can take a long time to go through forum threads but in software development when people come together as a community, problems and answers can be shared rapidly and often much quicker than trying to search for an answer by researching on ones own.

By performing good forum practice it not only resolved many blockages for the researcher it is good for the progression of games community, from professional, hobbyist and independent developer. Many forum threads can stay active for years and it can resolve problems for other developers for years to come.

5.8 Graphic User Interface Design

While working in the game industry the researcher had experience of working with Technical Directors and Games Designers who designed the Graphic User Interface (GUI) for a game. Their fulltime job was to design the GUI in conjunction with the TD and GUI artists. The overall progress was overseen by the lead artist and lead programmer and the style and direction of the interface will come from the Art Director. There will also be input from the audio engineer and if there is 3d content then 3D Artists and Animations can also get involved.

The researcher used the same process to design the interface and started by thinking about the end user, ailment sufferers, their families and general non specialists. According to Galitz “The goals of interface design are simple: to make working with a computer easy, productive, and enjoyable.” (Galitz, W. 2007 p. 1). By taking this into account the researcher wanted to move away from the complicated GUI that can come with games and make the interface design a simple experience.

Fig 48, Zane Bien, GUI Artist at Cloud Imperium Games (2015) z-design.deviantart.com

Figure 48 is an example of Zane Bien's work who is a graphic user interface (GUI) artist working on a trading game based in space called Star Citizen. Due to the complexity of the game there is a lot of information for the user to study. To a gamer this is needed to aid their game play. To a person wanting information about a medical ailment it might be too much information. After the evaluation the researcher can take into consideration any comments about the design of the artefact and add it to the future development section in the conclusion.

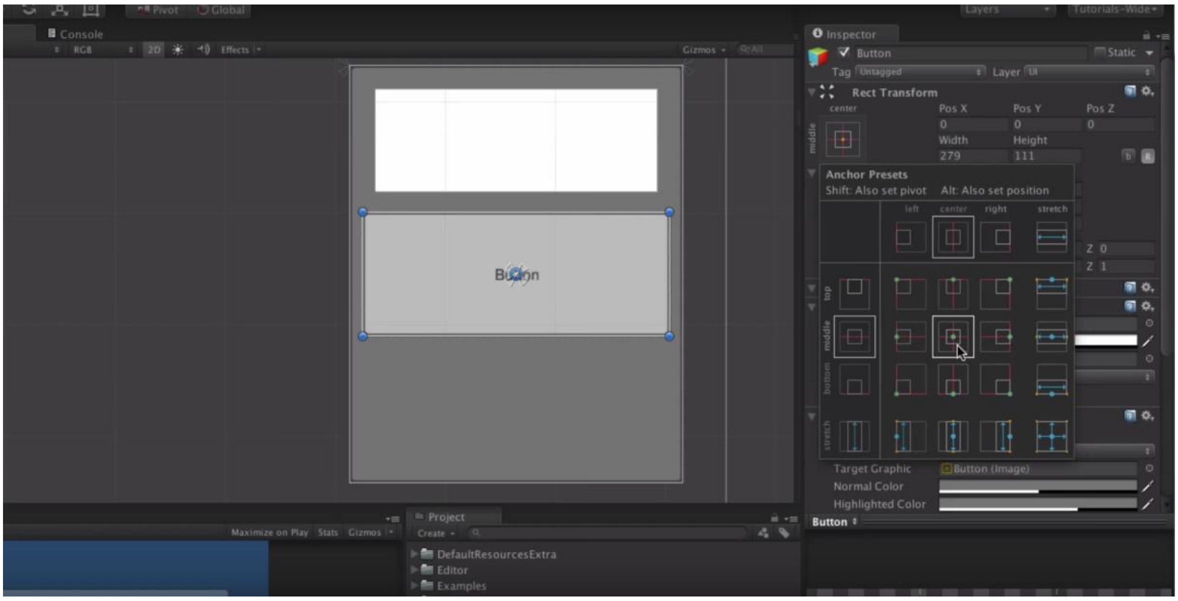

Fig. 49, Gallagher. N, (2013) (Unity button creation)

Figure 49 shows the starting point in building and positioning the components for the GUI buttons. It was achived by positioning and anchoring pivots to the camera. It all had to be mapped out and tested before designing the buttons to make sure the size and shape were not in the way of the simulation. According to Galitz;

> "Faster learning - research has also found that a graphical, pictorial representation aids learning, and symbols can also be easily learned." (Galitz, W. 2007 p. 22).

It is for this reason the icons have been designed and created using pictorial representation of organs, and for navigation there are symbols for direction with arrows. The symbols design for navigation where inspired and customised from media controls used on devises that are common in most households, giving users a clear and simple experience, which was also tested in the user experience (see the evaluation chapter for more details).

Symbol	Name / function
	Play
	Pause
	Stop
	Rewind
	Fast forward
	Skip to the start or previous file/track
	Skip to the next file/track
	Record
	Eject
	Shuffle
	Repeat

Fig. 50 Media Controls (2013) en.wikipedia.org/wiki/Media_controls

In figure 50 the icons can be commonly found on DVD, Stereo and Blu-Ray devices and the icons also appear on the devices player controllers.

In order to choose the style and colour of the icons, complementary colours where chosen, according to Steinberg;

> "Complementary colors are those that lie directly opposite each other on the color wheel. Complementary color schemes work best for drawings when you choose one hue as the dominant color and use its complement for accents." (Steinberg, 2011: 40)

Taking Steinberg's theory of complementary colours into consideration helped with the colour choice for the buttons. By giving the buttons an overall 'yellowed orange/orange' colour and placing them next to 'True blue/Light Aqua' the colours would be complementary.

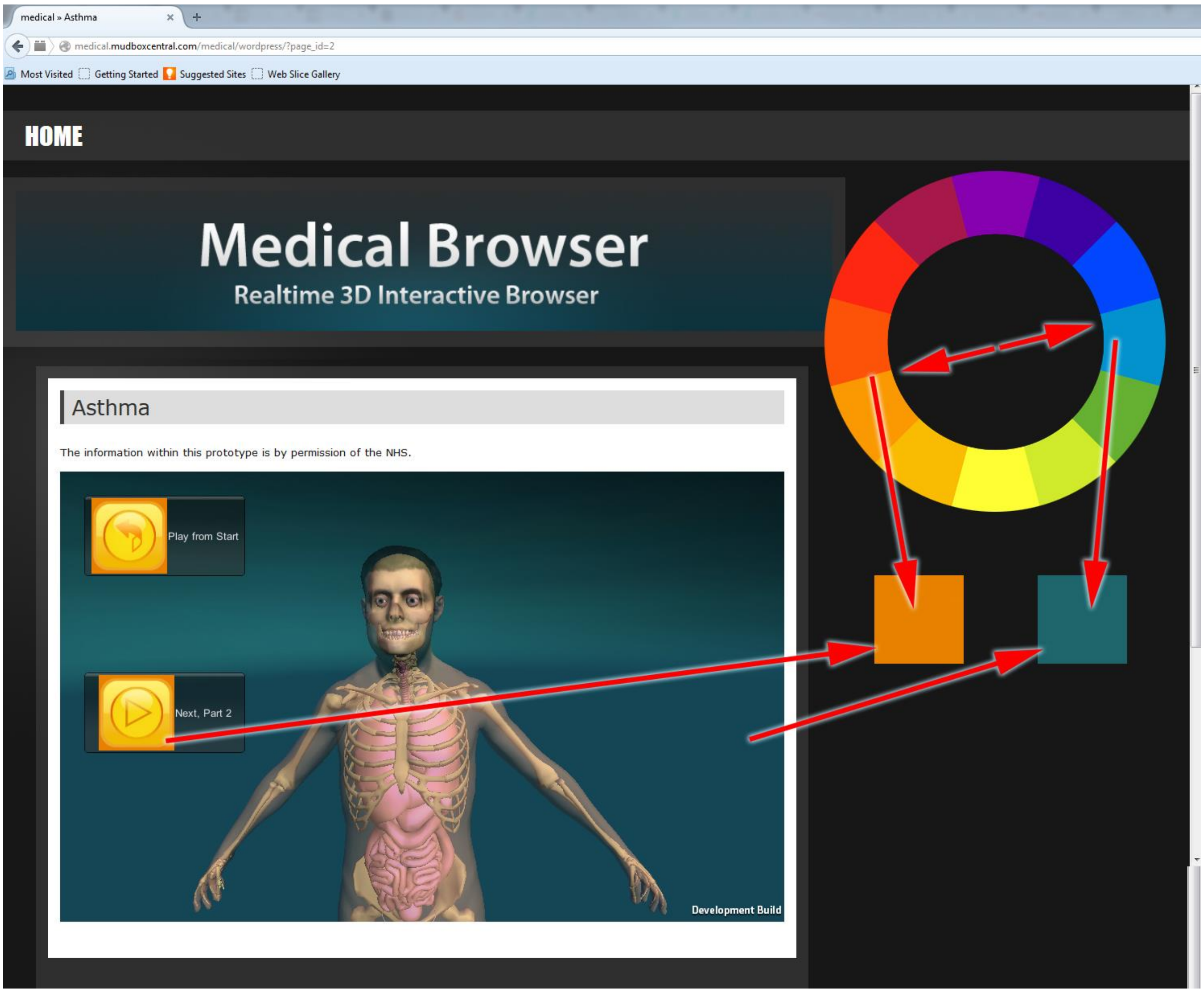

Fig. 51, Gallagher. N, (2013) *choice of colour for the buttons*

In figure 51 a colour wheel has been placed next to the web browser artefact. The arrows in the middle point to either side of the colour wheel to visually show Steinberg's theory in practice. The banner at the top of the website where it says 'Medical Browser' in large white letters, also reflects the colour of the background in the artefact to help the overall color scheme of the web page.

Fig. 52, Gallagher. N, (2013)

(Direction symbols)

Fig. 53, Gallagher. N, (2013)

(Pictorial representation)

Figure 52 is a selection of icons that appear in the artefact. When a user selects a particular button with one of the symbols, it triggers the simulation into a function such as next, repeat, skip and so on. The appearance of the icons have a direct relationship to the media controls icons in figure 50. This was produced to help with the user's common understanding of what is expected to happen in the simulation when a symbol is activated through mouse and click interaction.

Fig. 54, Gallagher. N, (2013) Direction symbols accompanied with text

In figure 54 the media control icons have been accompanied with text to help the user in case there is any misunderstanding of the icon.

Fig. 55, Gallagher. N, (2013) Symbols creation process

Figure 55 is a breakdown of how the buttons were created. Each button had a series of layers built up in Photoshop and then filters were applied to each layer and then graded. This was to soften the overall appearance so as not to overpower the message donated by the symbol. In the central circle an Omni grade has been placed from a light colour to the darker extremity of the circle to help attract the eye to the center of the icon (forth from the right). On reflection of the design, the highlight at the top of the central circle will be more transparent as it is proves to be the main focal point.

5.9 Visual Design

Due to the artefact being presented in a web browser there were limitations to the window size. The standard is currently 'Wide Super Video Graphics Adapter' (WSVGA) and this has an aspect ratio of ~17:10 which means the width and height of the pixels is 1024 x 600. This is due to consideration of backward compatibility on older PC, Apple Desktops and laptops having smaller screens.

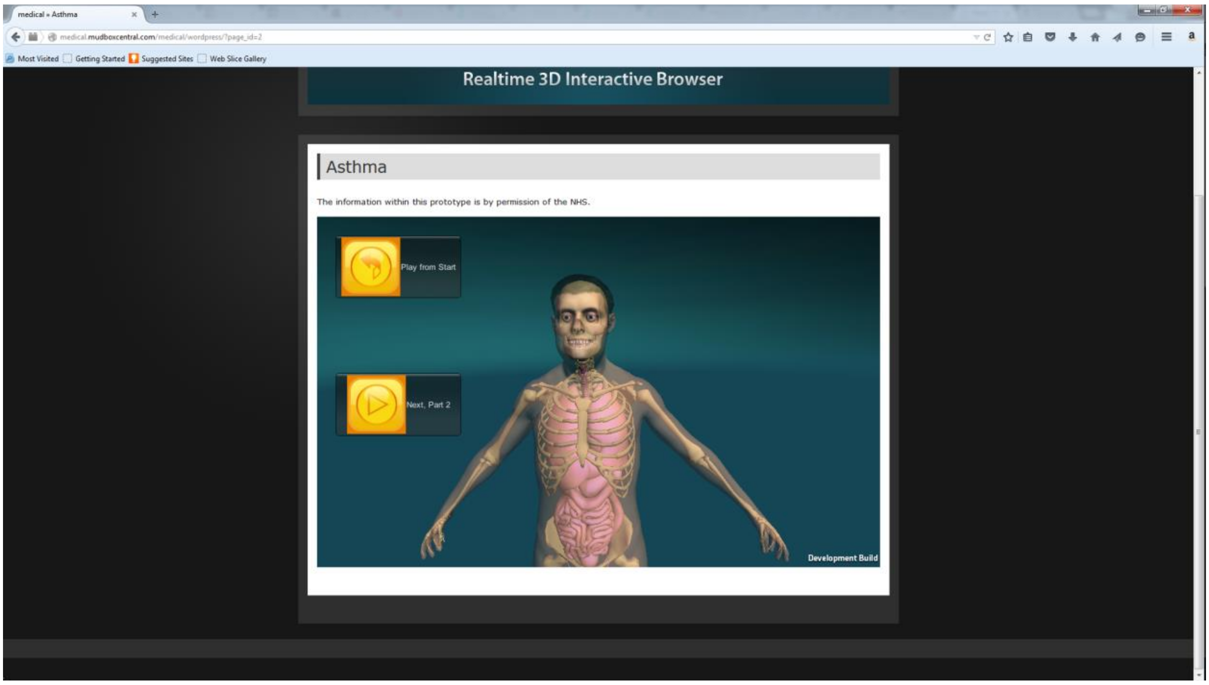

Fig. 56, Gallagher. N, (2013) (choice of colour for the buttons)

Working on the theory of humans being fixated on faces (see chapter 4.3 Functionality, 'Learning to Predict Where Humans Look') the focus for the texture detail was placed into the face, and flat colour was used for the bones, organs, skin and background colour. Vertex colour was used to help give some areas gradients of colour.

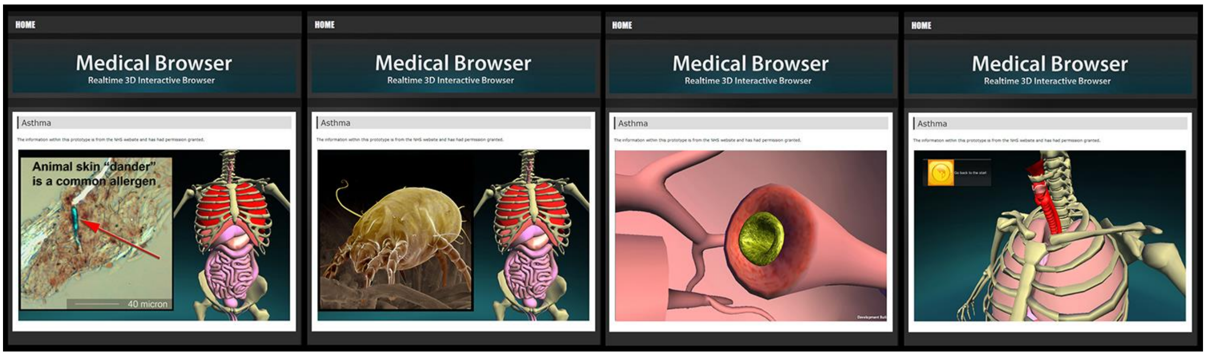

Fig. 57 Gallagher, N. (2013) Artefact, choice of flat colors. medical.mudboxcentral.com.

The realisation became clear that not all the texture slots could be used in the material slots inside Unity. This was due to a limitation in Unity Web Player export. The reason is that each time you add a texture to a polygon the calculations in its ability to render goes up as it uses more processing power on a computer. This also has a direct effect in the overall file size of the export, due to it reducing the speed of the download dramatically due to it having less information in the form of texture data.

When a games artists textures a digital human in on games consoles such as the Xbox 360 and PS3. There are three main textures used; 'defuse map' used for the colour of the skin, 'normal map' which allows simplified low polygon meshes to look like they have lumps and bumps and small details to much larger details such as muscles. And a 'specular map' controls the highlights. In order to keep the file size down to under 10mb there was a choice of only choosing two textures so Defuse and Normal maps were chosen and then a flat specular colour was applied through the material.

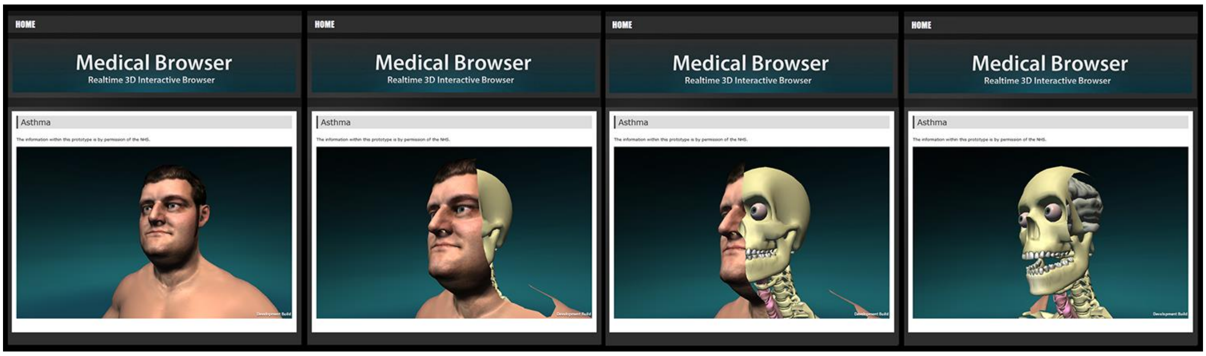

Fig. 58 Gallagher, N. (2013) Artefact, choice of flat colors. medical.mudboxcentral.com.

Some materials were crude due to limitations in unity, for example a subtle transparent edge fade would have been a desirable effect, see figure 58 but "semitransparent shaders do not write into the depth buffer. This can create 'draw order' problems, especially with complex non-convex meshes" (Unity Shader Lab: Culling & Depth Testing 2015). Also file size efficiency was always a priority due to load times and is discussed further in Chapter 5.12 Further Development.

5.10 Information and Navigation Design

To help with the navigation design the starting point was to research into reviewing the medical simulation market. Then came the process of getting a prototype up and running, according to Benyon;

> "The Key thing for designers to remember is that they are not the people who will be using the final system. Designers need to understand the requirements of other people. This is not easy, but talking to people using interviews" (Benyon 2012:150).

As Benyon explains, the early prototype was too complicated, it was built with the researcher in mind as the end user, see Chapter 5.1 (Testing Games Engine Delivery Technologies). By talking to industry professionals like Cullum Welsh and work colleagues in the office about the early medical artefact it became clear that there was too much interactive content.

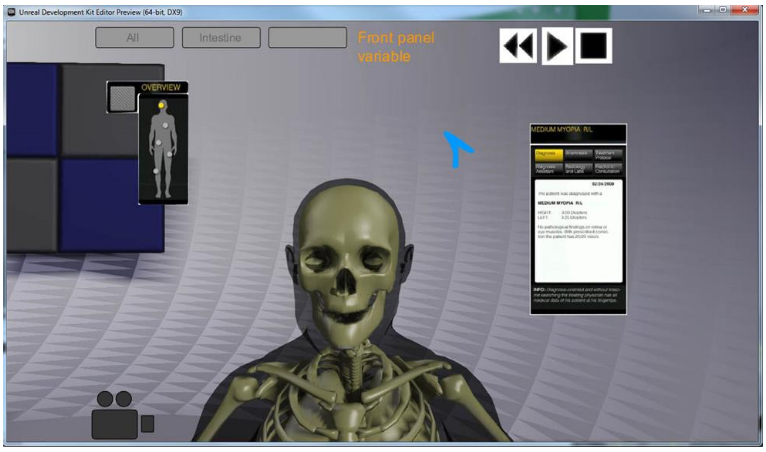

Figure. 59 Gallagher, N. (2013), Screen shot an early prototype.

As can be seen in figure 59 there lots of flip up charts and by clicking on some bones or organs, a flip-up chart would appear. The user was then presented with information about the organ. The various charts could be moved around the screen and also clicked on for more information. This would then activate the camera to move to a new part of the body. Users where saying the interactive experience is too complicated for the general public and it did not tell a story, it needed more focus and simplification.

By listening to advice and reading interviews about how to start a medical simulation company, such as an interview with Bruce Blausen, Gaglani;

> “When people are diagnosed with, for example, cancer, they really cannot process the information being given to them. They are freaked out. Our animations help educate them and address their concerns about treatments or procedures”. (Gaglani 2012).

The researcher felt that the contents on many medical websites could be complemented with an interactive 3D approach by delivering extra content that a 2D video cannot offer. For example having a mouse controlled 3D camera would allow the user to pivot around an organ to help gain a better understanding of the organ's shape, form, size and the audio would explain its function when selected. 2D symbols would reveal the triggers of asthma with audio and more imagery. To expand on this there is an area in the artefact that enables a free rotating camera driven from mouse control, centered on a particular organ, in this case the thracia. This was created to show it is possible to gain a perspective on an organ's shape, size and relation to where it is located in the body. To make it more obvious for the user the various organs transfer colour with an offset delayed subtle pulsation to become highlighted in red for more information. When the user selects an organ of their choice via a mouse click a cinematic is triggered accompanied with an audio explanation of what the organ is.

5.11 Hardware and Software and Platform Possibilities

Currently the artefact works on Windows PC, Apple/Mac and Windows Surface Pro Tablet. Now the researcher has an understanding of programming it is possible to expand on delivering computer games simulation content in future developments on lots of different hardware platforms.

In an interview with Mr Blausen about Blausen Medical Communications, according to Gaglani;

> "Over 1,000 3D illustrations and animations (apparently each costing \$10,000 to create, making the total app's development worth about \$10 million)" Gaglani (2012).

When Mr Blausen was asked in an interview, about how Blausen started off his own medical visualization company he said;

> "I just looked at it more or less like a field of dreams. You know, build it and they will come. So we just built 50 topics and, all of a sudden, the compression and the internet capabilities caught up with us, and we were able to license them to hospital systems for use on

> their intranet backbones. And as the technology took off, so did Blausen Medical Communications." (3DArtist 2013)

Now the researcher has tried the discipline of being a technical artist there is a larger understanding of games engine architecture. It is possible to see the limitations of the Unity Web Player plugin through the process of understanding the basics of JavaScripting and seeing firsthand the physical data attachments to the plugin, and how it connected to the different browsers. This is an issue for a number of reasons. Firstly the developer is dependent on browsers supporting a plugging and secondly the developer is also dependent on the vendor continuing support for a technology that currently is not its main focus. What 3D Web browser technology needs is a solution to work without plugins which up until now have been Flash, Java and Unity Web Player. According to Parisi;

> "The industry is also pulling together to create new 3D file format standards designed specifically for web use. The content creation landscape is still a bit rocky, but at least we have moved beyond the "stone tools" stage of a few years ago into more of a Bronze Age of 3D development. 5.12 (Parisi, 2014: 8)

5.12 Further Development

The researcher can now debug and package more simulation content on different platforms from the Unity Games Engine, including Windows, OS X, Unity Web Player, Android, iOS, BlackBerry 10, Windows Phone 8, Tizen, WebGL, PlayStation 3, PlayStation 4, PlayStation Vita, Wii U, Nintendo 3DS line, Xbox 360, Xbox One, Android TV, Samsung Smart TV, Oculus Rift, HTC Vive and Gear VR. All the tools are open for creation and it is possible to publish for free, or for a small royalty fee dependent on the licensing from the vendor.

According to the Unity website;

> "While WebGL is a very exciting new technology, currently, the Unity Web Player is still the most feature-complete and the most performant solution for targeting the web with Unity, and will stay as a supported platform in Unity 5.x. It may be a very useful strategy to dual-publish your content using both WebGL and the Web Player, in order to get the widest possible reach for your audience" (Unity WebGL, 2015).

Further development on this study might be to go in two branches as the Unity Website suggests but equally if another vendor produces a pipeline to enable 3D web browser content with many of the features a games engine can bring and work without plugins then it is not a problem to learn a new engine. In regards to learning WebGL and HTML5, according to Parisi;

> "As of this writing, 3D feature coverage is not complete across the various browsers. Also, each browser supports a slightly different subset. Clearly, this is not an optimal situation, but it's the sort of thing that comes with the web application development territory. Cross-browser support has always been notoriously difficult; with the explosion of features in HTML5 and the proliferation of devices and operating systems, it hasn't gotten any better. The only consolation is that the alternative is far worse: native applications are even harder to build, test, deploy, and port. Oh well…such is the life of a web developer in the 21st century. (Parisi, 2014: 1)

The current state of 3D web technology is that there is no single clear distribution method. Further development of this study might be to break up the digital human body to allow for better clarity of the model, partly due to the download speed of the artefact being around ten seconds on a 10mb broadband network. There has been a lot of new learning on anatomy, reviewing medical artists work, reading about anatomists and reading about the history of medical visualisation. A common theme in the history of medical visualisation is the collaboration of the subject between anatomist and artist. It is for this reason the next step will be to find an anatomists that has an interest in the area to help validate the contents of the future development of the artefact. Then follow the same evaluation process that has been achived in this study. By working with an anatomist will help validate the digital human on issues such as proportions, naming, colour, placement and many more issues.

Rather than producing an entire human model, this time the researcher will break the human forum down into smaller components. This will allow for fast turnarounds of content to help build a portfolio of content and will help with adding more details such as skin details, muscle, veins, bones focusing on joints or a particular organ at a time. It will also speed up the web browser experience.

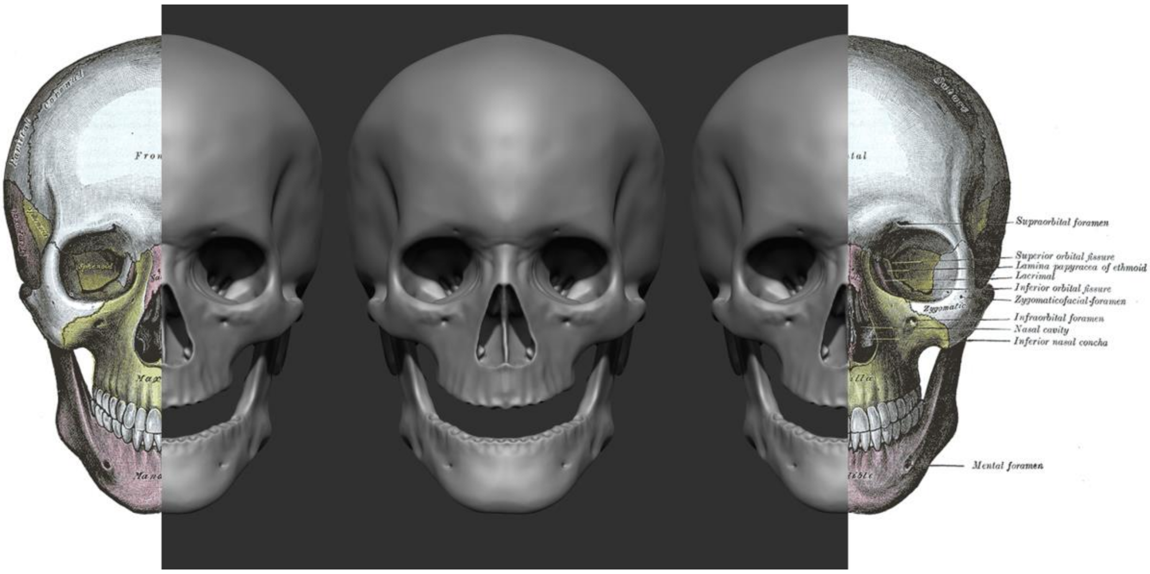

Fig. 60 Gallagher, N. (2014) 3D further direction, practice over Gray. H (2014) en.wikipedia.org/wiki/Human_skull

The researcher digitally sculpted a new 3D human skull to a higher resolution. This was produced by overlaying the digital sculpt onto top of a drawing by Henry Vandyke Carter (1831 - 1897) to help with proportions. During the study it was decided that a 3D Scan might produce more accurate results then working from flat 2D drawing. For example where the vertebrae connects to the base of the skull it has some very complex shapes around this area.

Scan data can be combined with current games art topology practices and produce better optimised results for web browser creation.

Creating 3D from photos is called 'photogrammetry' and allows for photo imagery and 3D data to be produced at the same time. The researcher posted on some forms and joined some 3D Scanning groups on social media to learn more about the subject. The researcher started a thread called 'Photogrammetry Thread, Best Practice' on a forum called *'Polycount'* (2014). It received lots of useful information from the digital art community and two pieces of software were mentioned by industry professionals that were using it on their current industry projects. Example videos and articles were also posted. The two most common photogrammetry software's mentioned where 123D Scan by Autodesk (2014) and Agisoft PhotoScan (2014). By following the advice on the thread a self-portrait was produced using photogrammetry methods. To test the software a quick test with a Samsung 3 mobile phone proved to give a 3D mesh. Next a Cannon 5D DSLR produced a cleaner 3D mesh with less errors but due to the amount of photos being taken there was some natural movement from breathing.

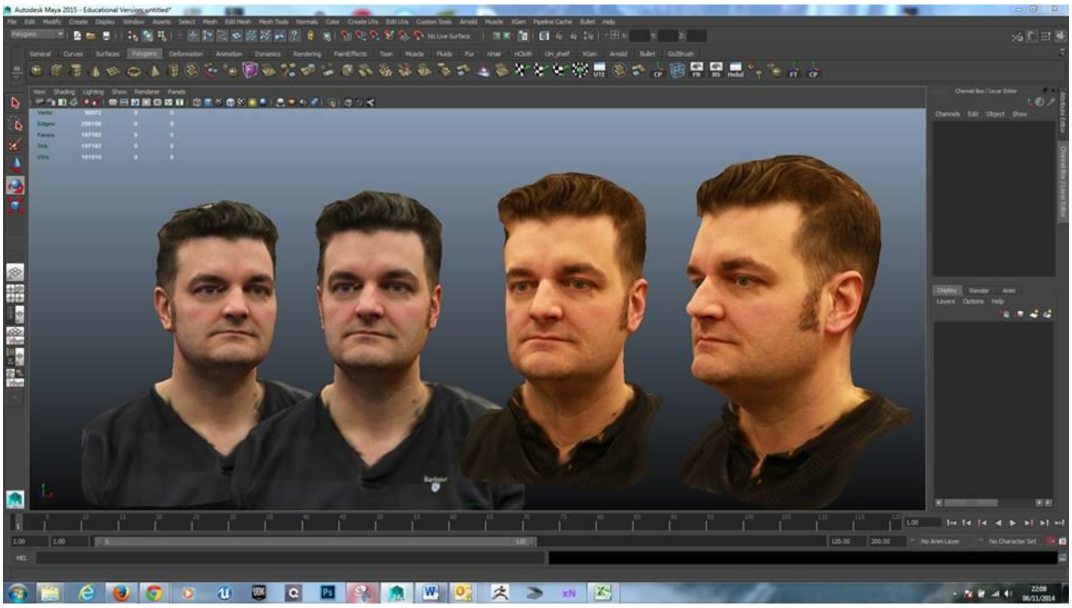

Fig. 61 Gallagher, N. (2013) photogrammetry with a Cannon 5D DSLR to 3D model

In order to capture a pose from life in an instant and have less movement a bank of Cannon 5D's were set up on tripods and set up in an area with lots of bounce light but no dominant directional light. The environment must be very still with no background movement not even in reflections. This proved to give a high resolution 3D model and is starting to look as though this could be the way forward for further developments.

Fig. 62 Gallagher, N. (2013) Photogrammetry

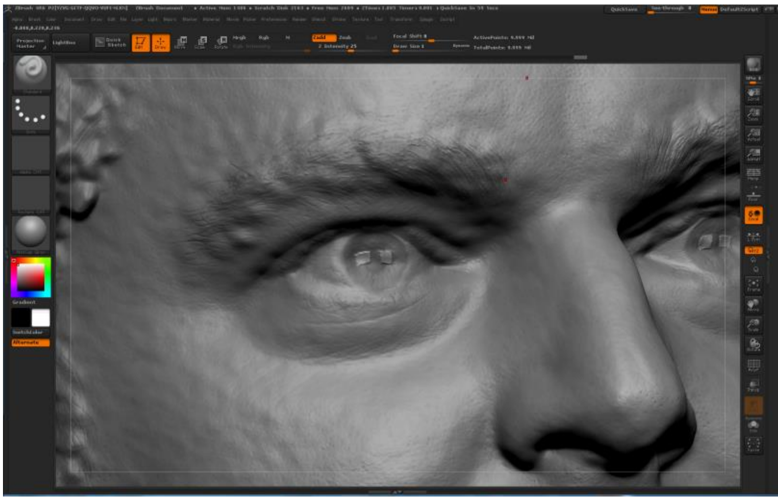

Fig. 63 Gallagher, N. (2013) Photogrammetry

Fig. 64 Gallagher, N. (2013)

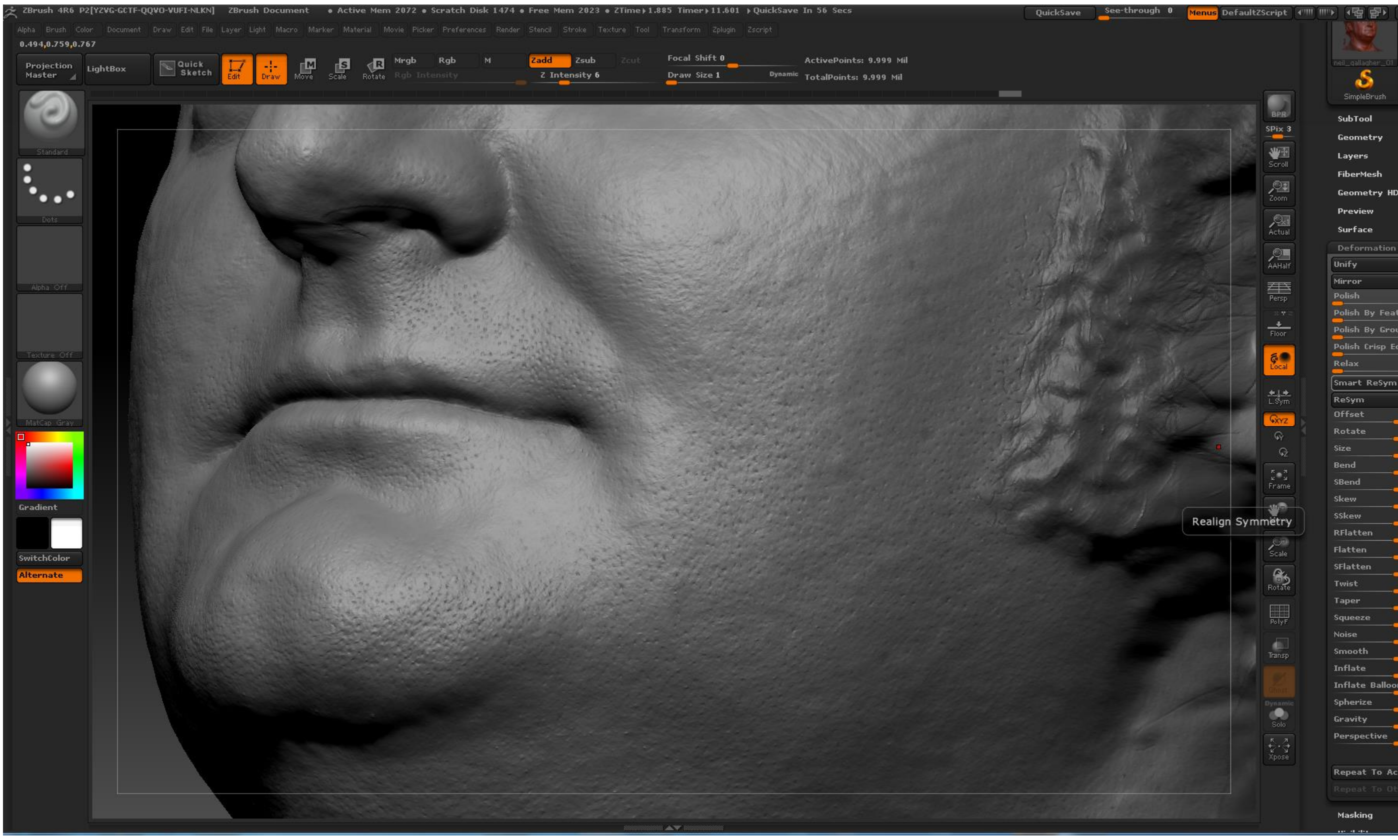

Fig. 65 Gallagher, N. (2013) Photogrammetry

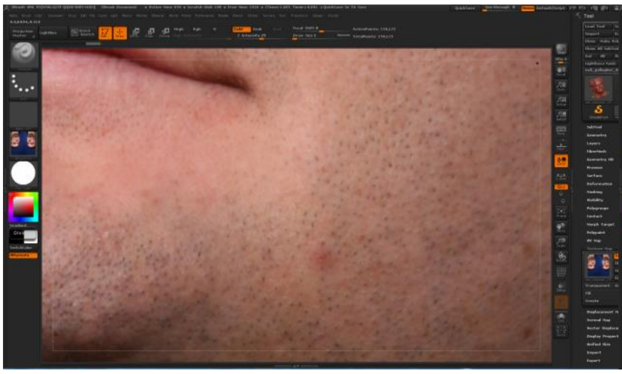

Fig. 66 Gallagher, N. (2013)

Photogrammetry

Fig. 67 Gallagher, N. (2013)

Photogrammetry

In figure 67 are the results of photogrammetry with skin details holding up with a close range camera. The next process was baking down the information from hi to low resolution polygon mesh to investigate if it could keep the information. The software used for this process varied to get sharp results. In the end ‘diffuse map’ was created in Autodesk Mudbox. The ‘normal map’ was made inside XNormal. And ‘specular map’ inside Zbursh and Photoshop to clean up the textures.

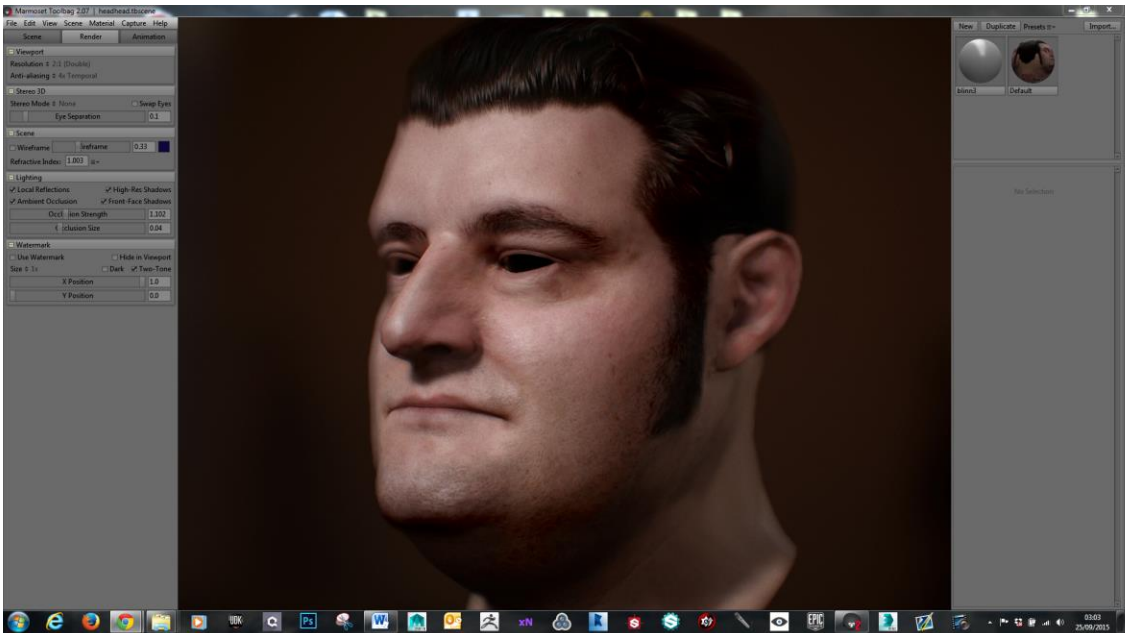

Fig. 69 Gallagher, N. (2013) Further development, Real Time, Low Resolution Model, collection of 4 images.

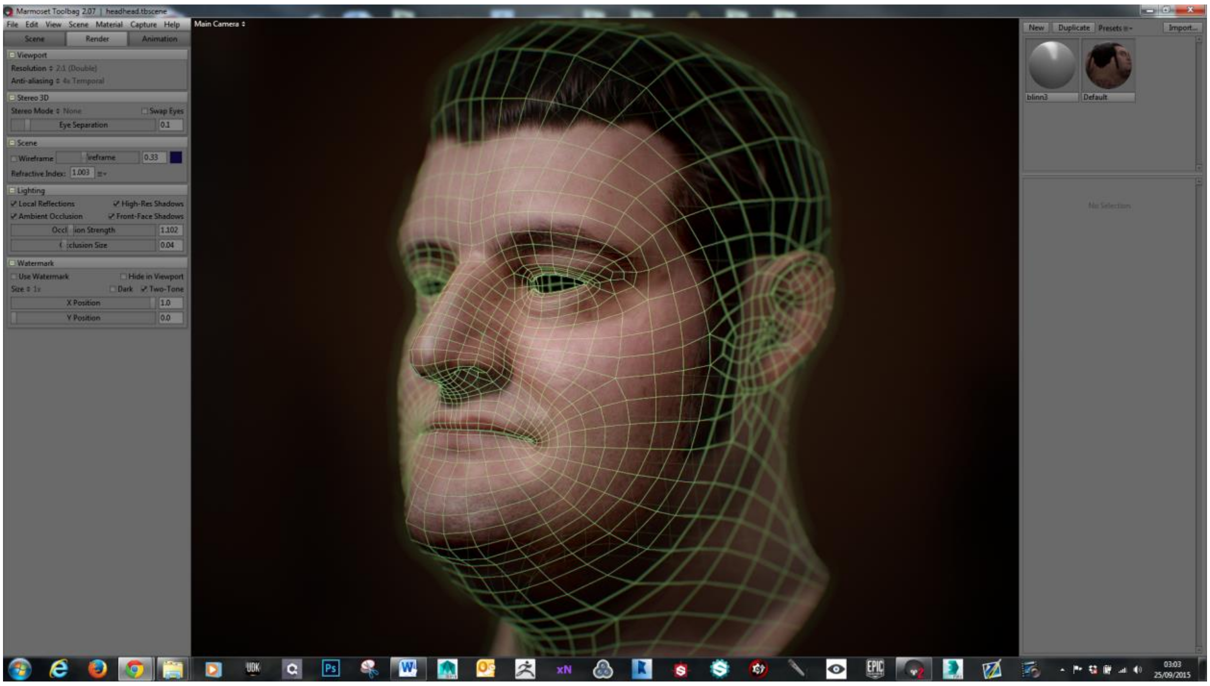

Fig. 70 Gallagher, N. (2013) Further development, Real Time, Low Resolution Model, collection of 4 images.

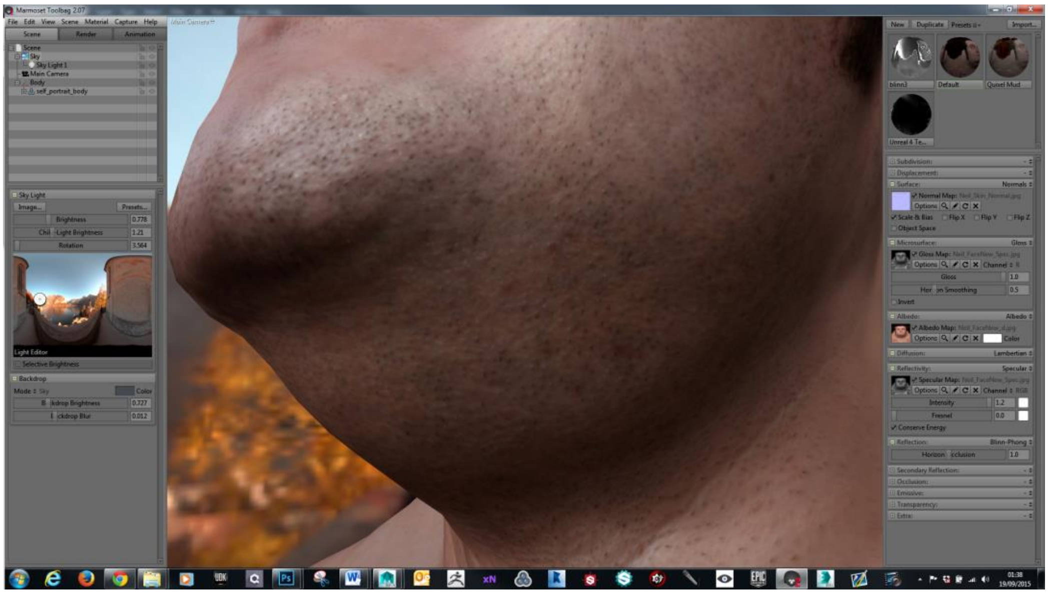

Fig. 71 Gallagher, N. (2013) Further development, Real Time, Low Resolution Model, collection of 4 images.

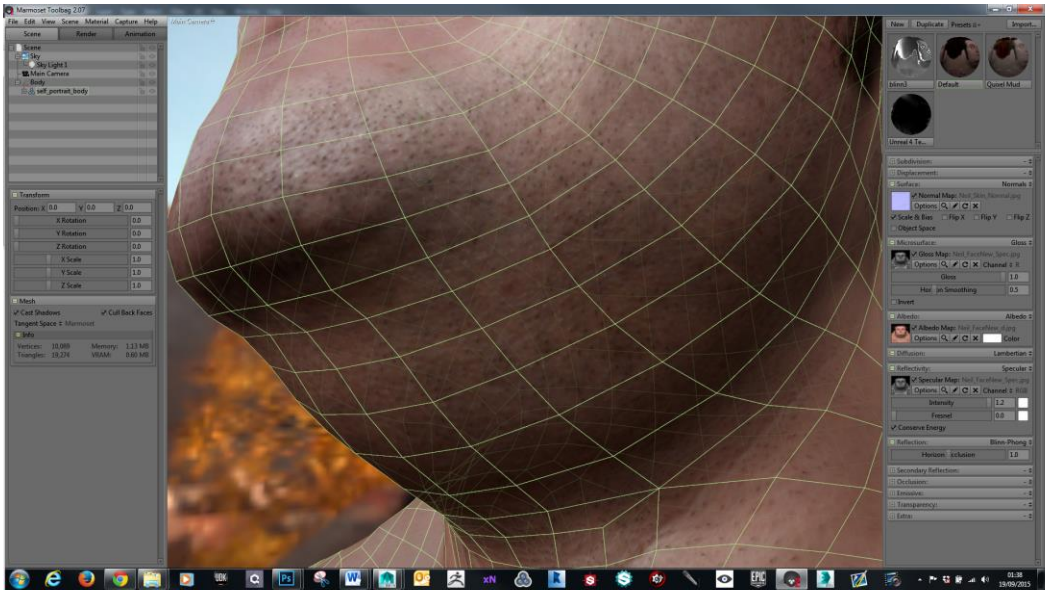

Fig. 72 Gallagher, N. (2013) Further development, Wireframe Real Time, Low Resolution Model, collection of 4 images.

Figure 72 shows an updated model that is in a real time games engine using the process of Photogrammetry. There will be more development spent on refining the low resolution topology for animation purposes and capturing more of the high resolution subtle shapes and anatomical details to the form of the face. A human skull, mandible and some upper vertebrae will also go through the same process.

Another way forward would be to work from 3D Magnetic resonance imaging (MRI). This would be the most labour-intensive method but would provide very accurate proportions. The benefit to working in this method would be the accurate process of adding 3D models in the correct place, for example organs, muscles, tissue, tendons and nervous system.

In order to get hold of (MRI) scan data could be from the contacts made in the medical and visualization areas. Another could be to approach companies such as BodyViz as they sell high resolution 3D MRI, CT data scans (BodyViz 2015).

Fig 73 & 74, Body Viz (2015) bodyviz.com

This will allow for further development of the project to expand one body area at a time and produce some ailments based around a digital human head as a starting point. Further development will be to expand this process to one body area at a time and use the interactive techniques used in the creation of the artefact to build a portfolio of ailments.

5.13 Realisation: Summary

Games engine technology is not quite ready to release HTML5 authoring tools for development, at the time of writing. Unity and Unreal both have tech demos and mention on their website the technology is close to being released. If a different engine was to release 3D web browser delivery tools before the Unity game engine, then the researcher has no objections to developing on a different platform should one become available.

The future direction for 3D Web technology looks like WebGL working on HTML5 is the solution developers are looking at using. Microsoft Internet Explorer version 11 has prefixed WebGL 3D to catch up with the other web browsers which have already done this. It means 3D Web Technology is ready on the browsers and as the public update their software it will just need an authoring tool to become available from a vendor to get 3D Website content on the market.

The artefact was a test platform in order to test 3D web browser technology as an aid to help Asthma sufferers as set out in the research questions. A possible solution for the researcher now there has been a lot of new learning on anatomy, artists, anatomists and the history of the subject will be to work alongside an anatomist. Rather than developing the entire human body, the aim is to focus on one body area at a time.

High level detail is proving to be possible in real time due to new Photogrammetry software tools and new high resolution DSLR digital cameras and the technology they bring.

The release of each games console showed the rapid rise in polygons and now there are lots of new post process effects and techniques to make real time 3D look better.

There are new development tools in real time rendering techniques in the film and TV industry which are starting to produce new software and opens up research and development tools outside of purely console development. It is allowing for techniques that are going beyond the graphics capabilities of current games consoles, tools such as Digimania (Digimania 2015) and Autodesk Stingray (Stingray 2015) and they have only come onto the market at the end of summer 2015.

6.0 Evaluation

This chapter evaluates the product in three different ways, as described below. The researcher used three different ways because of the method of triangulation. This makes sure the research data is not from the way the researcher tested the artefact but actually from a property of the artefact itself, so that the data is reliable.

To help answer the research questions a user test was setup by the researcher to test the artefact on asthma sufferers and validate it for its communication. Medical professionals also tested the artefact to help validate it for its overall accuracy.

6.1 Functional Tests

This section looks to see if the functional tests driven from the Statement of Requirements from Chapter 4 have been met. The table below is an overview of the main points.

Statement of Requirements	Comments	Yes	No	Partly
<u>**Content**</u>				
3D works in a web browser		✔		
Audio		✔		
Collision Meshes (organs selected)		✔		
3D Cinematics		✔		
Lens control (FOV)		✔		
Vertex lit				
Website works		✔		
Images		✔		
Textures	Textures are very expensive for data memory, future development will look into new software 'Algorithmic Substance' surfaces.			
Text	Text is on the button and some pop ups. A new feature to accompany the audio will be text. This will also be good for deaf people.	✔		
Lighting		✔		
Animation		✔		
Explains causes of asthma	The nurse mentioned "what treatment is available". It would be best to hyperlink to the NHS, or advise to seek a medical professional for ethical reasons, needs more planning and will be added.	✔		
Triggers on GUI buttons move the 3D camera.		✔		

Materials for the surfaces		✔		
Functionality				
Rotational mouse driven camera		✔		
Point and click on three dimensional models (organs)		✔		
Buttons allow for more information		✔		
		✔		
Unity Web Player - Plugin works		✔		
Simulation is bug and crash free		✔		
GPU Skinning		✔		
Delivery Platform				
Web Browser		✔		
PC		✔		
Apple Desktop		✔		
Tablet (Surface Pro)		✔		
Web browser - Goole Chrome		✔		
Web browser - Internet Explorer		✔		
Web browser - Safari		✔		
Web browser - Firefox		✔		
Content is Streamed		✔		

To summarise the results as can be seen in the Statement of Requirements, the functionality has been achieved. There were a few minor points brought up that need to be revisited but overall the assessment was positive from both the target user group and the medical professionals.

6.2 Survey Results from Qualified Medical Professionals and Practitioners

There were two medical experts' opinions collected, a medical doctor and a trained nurse. The medical expert's responses have been collected and inserted into tables (for full questionnaire see appendix v.).

The table below is a quick look up table to give an over view of the results.

Likert scale						
Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree
4	2	3	1	0	0	0

Question three was particularly important as it was a research question and a statement of requirement. “Did you feel that the simulation is an accurate description of asthma triggers and their symptoms?” and the results were ‘Strongly Agree and Somewhat Agree’.

There are some valid points made mainly around animation and audio. They are not only important but will make the product more interesting for the user experience; this will be achieved in future development of the artefact.

To address all the issues will be push the technology of what is possible for 3D content through a web browser without affecting the framerate. The solution on the new artefact will be to have a hardware cut off and not to put so much emphasis on backwards compatibility as the current artefact has done.

Overall the medical professional user test was positive and a success with comments such as, “Very well detailed and explained, I strongly agree, Very effective, I think it would very useful”

6.3 Target User Survey Results

This chapter covers the questionnaire results. The data was collected from a website called ESurv which provides tools for making online forms, surveys and polls (ESurv 2015). The answers and data have been collected and placed into tables below. In the pie charts below the numbers were rounded to the nearest number. As there were six user testers it has no affect the final result. (6 ÷ 100 = 16.6 - recurring) (for full questionnaire see appendix iv.).

The user testing on target users was broadly an overall success with a high proportion on the question answering in the Agree to Strongly Agree area. Overall they found it communicates effectively with particular success in areas such as “understand on the subject of asthma, enough information about the causes of asthma, how does this simulation compare to pamphlets, information on External Triggers” all scoring highly.

They did identify a few aspects which need to be considered further as two questions dipped into the negative based around the photo imagery. This clearly shows an issue around this area and needs further investigation. The last comment might be the direction of the solution, by adding audio and text to the imagery. It would then take further tests to see if it comes up again.

The process now will be to take all the comments and make sure they are in future developments of the new prototype. ‘Text’ for example is now an easy solution in the Unity engine as 2D text with very low memory cost has been enabled rather than using texture images. This will also allow deaf and hard of hearing people have an easier time using the artefact.

In summary the target user, who are asthma sufferers believed the artefact was able to communicate effectively. They did identify a few aspects that need to be considered further to help move the product forward in future developments. And the medical professionals helped validate the contents for its accuracy and again the feedback from them was prominently positive.

6.4 Realization: Summary

Overall the user testing was broadly a success. Question three for the medical professionals was particularly important as it was a research question and a statement of requirement, and there was overall agreement by the medical experts that the simulation was an accurate description of asthma triggers and their symptoms.

There are some points that will need addressing in future developments of the artefact. Some will be easy to address where as others need more research and development. In terms of functionality, overwhelmingly most of the objectives were meet.

There was mention from the nurse to add medical products which have been thought about in the past. The researcher had also been planning a tutorial on how to administer medical drugs. Both of these points would need strict ethical clearance and validation from a medical expert. It may be a better solution to build more resources and content and then revisit this matter in the future.

Overall the user testing has proved to be insightful and brought up many points. The researcher has achieved what was set out to do in the research questions and the Statement Requirements. This chapter concentrated on the evaluation of the prototype. It did this from a number of perspectives, and concluded that broadly the project aims have been a success.

7.0 Conclusions

This chapter summarises the extent to which the research outcomes have been met and new knowledge produced.

This research project aimed to discover if it is possible to deliver a health communication tool using online 3D web browser technology. There were four main research questions (see chapter 1.1.1).

1. Is it possible to produce a 3D medical visualisation system that works through a web browser?

2. Is it possible that such a system can communicate effectively to a target audience using a 3D medical simulation that works through a web browser?

3. Is the artefact an accurate description of asthma triggers and their symptoms?

4. What are the learning outcomes taken from user testing the prototype on asthma sufferers and medical professionals?

Based on the evaluation of the outcomes in this research project, it is clear that the research questions have been answered.

7.1 Achievement of Research Outcomes

The project has proved that with current online 3D web browser technology it is possible to deliver a health communication system. It is able to communicate effectively to a target audience and, as the medical experts have confirmed, it actually provides useful and accurate information (see section 6.2).

7.2 Contributions to Knowledge

This project has confirmed that it is now possible to deliver a real time browser based 3D simulation, for use as an information tool for health communication purposes. This tool can be created by modifying an existing games engine. The tool developed to demonstrate this comes with interactive elements and has the potential to complement current health communication systems such as pamphlets, magazines, posters and so on.

The artefact was built to communicate on the subject of asthma and it was user tested on a group of six asthma sufferers to prove it can positively communicate to them. Two medical professionals, a doctor and a nurse reviewed the artefact to confirm its medical accuracy. The artefact for both tests was broadly a success and proved that online 3D Web Browser technology can broadly deliver health communication. The points that were raised in both user groups comments will be addressed in future development of the project.

7.3 Suggestions for Future Development

The new artefact's focus will be on the creation of smaller body areas with more detail. Currently much research and development indicates that the solution is to move towards WebGL on a HTML5 web platform due to it being native on current web browsers.

The researcher will work with an anatomist from the outset to build a digital model to help validate the skull, tendons, nervous system, muscles and organs. Content inside the digital head will be based on MRI scan data. Retopologising MRI scan data will allow for greater accuracy in the low polygon model. The latest real time digital art methods in retopology and bake down methods, along with algorithmic materials will result in interesting developments in this area, especially in animated versions of muscle groups.

7.4 Closing Remarks

I started this health communication project due to personal experience of a family member suffering from asthma. I also wanted to help future generations by creating new health communication tool. This project has been a very interesting learning process and the possibility of making a difference to future health communication is a very exciting prospect. I am hoping to extend this project by looking at more diseases and by producing medical health communication experiences that the public can access on the web.

For now I look forward to concluding this study and exploring WebGL HTML5 and to see what is possible. A serious games modification team for health communication will also be the focus to gather like-minded people in order to grow the content.

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Fig. 63 Gallagher, N. (2013) Photogrammetry, Screen shot from Researcher work on a PC

Fig. 64 Gallagher, N. (2013) Photogrammetry, Screen shot from Researcher work on a PC

Fig. 65 Gallagher, N. (2013) Photogrammetry, Screen shot from Researcher work on a PC

Fig. 66 Gallagher, N. (2013) Photogrammetry, Screen shot from Researcher work on a PC

Fig. 67 Gallagher, N. (2013) Photogrammetry, Screen shot from Researcher work on a PC

Fig. 68 Gallagher, N. (2013) Further development, Real Time, Low Resolution Model, collection of 4 images , Screen shot from Researcher work on a PC

Fig. 69 Gallagher, N. (2013) Further development, Real Time, Low Resolution Model, collection of 4 images.

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Appendix

vii. **Email Correspondence**

viii. **Email, Permission from NHS**

ix. **The Contract from the NHS, Permission of use, copyright and database**

x. **Questionnaire Feedback from Asthma Sufferers**

xi. **Questionnaire Feedback from Medical Experts**

xii. **Forum Threads, Q&A strategies**

i. Email Correspondence

1. Callum Welsh, Art Director at Random 42 Medical Animation

   Email, Callum@CallumWelsh.co.uk

"The next generation of real time graphics technology such as UE4 and Unity is going to see huge improvements in real time graphics and may even replace rendering medical animations altogether as the demand for real time visualization will grow and clients will expect to see both a finished animation and an interactive demonstration. Currently there is a huge gap in the market for Tablet and web based visualization".

2. Martin Bowman, Senior Lecturer At the University of Hertfordshire

Email, m.p.bowman@herts.ac.uk

"An interactive tutorial would be a fantastic benefit to asthma sufferers, especially children who have a hard time learning how to use an inhaler correctly. I taught my younger brother how to use his inhaler after realising that he was not using it as the asthma nurse had described to me, and consequently was not getting the relief from symptoms that he should have experienced. (Worse still he was spending a lot of time in hospital because of this).

If there was an interactive tutorial that demonstrated, step by step what the child should do (correct body posture, getting the breathing to a regular series of deep breaths, understanding to trigger the inhaler as the breath is sucked in, and then holding their breath for the required time period etc.), that could help either a child on their own dealing with the issue, or act as a memory aid to an assisting adult. Both child and adult would feel more in control of the situation, with the hope that the medication would be administered correctly and therefore reduce the likelihood of a visit to the Accident and Emergency ward".

ii. Email, Permission from NHS

The following email correspondence was with the National Health Service in order to ask for permission to use information from their website.

-----Original Message-----
From: NHS Choices [mailto:thechoicesteam@nhschoices.nhs.uk]
Sent: 13 June 2012 16:44

Dear Mr N. Gallagher,

Thank you for your correspondence of 13 June about using information from the NHS Choices website. I have been asked to reply.
You may re-use this information free of charge in any format or medium, under the terms of the Open Government Licence.

To view this licence, visit:
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or write to:

Information Policy Team
The National Archives
Kew
London
TW9 4DU

iii. The Contract from the NHS, Permission of use, copyright and database

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Back to The National Archives

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iv. Questionnaire Feedback from Medical Experts

Here are the user test results from the medical experts.

User Survey Results: Qualified Medical Professionals and Practitioners		
1) I confirm that I understand that I can withdraw at any time and confirming yes means that I agree to participate in this study.		
	Response (%)	**Responses**
Yes	100.00	2
No	0.00	0

Question 1:

Did you feel the product provides an accurate and coherent account of the processes and symptoms of Asthma? Given that this product is designed for patients and their families (rather than medical specialists) and sets out only to explain the underlying causes and effects of asthmatic illness.

Likert scale	Responses
Strongly Agree	0
Agree	1
Somewhat Agree	1
Neutral	0
Somewhat Disagree	0
Disagree	0
Strongly Disagree	0

Respondent	Likert Opinion	Further comments
Nurse	Agree	I would have liked the presentation to include what treatment is available and advice on when to seek urgent medical attention.
Physician/ Specialist in Anesthesiology and Intensive Care.	Somewhat Agree	I believe that it is helpful to use English terminology (e.g. windpipe, voice box) rather than Latin when communicating with lay persons. If at all possible have the air symbols pass inside the airways.

Question 2:

How did you feel the verbal and visual presentation communicated the accuracy of the symptoms of asthma?

Likert scale	Responses
Strongly Agree	0
Agree	1
Somewhat Agree	1
Neutral	0
Somewhat Disagree	0
Disagree	0
Strongly Disagree	0

Respondent	Likert Opinion	Further comments
Nurse	Somewhat Agree	I liked the biology part but patients then want to know how it affects them so perhaps the model actually having a (simulated) asthma attack and the sound of the "wheeze" may be useful. The commentary kept repeating around the asthma triggers part and it would have been better commentated by the same person throughout.
Physician/ Specialist in Anesthesiology and Intensive Care.	Agree	The main characteristic of asthma is that it is a completely reversible process mainly caused by spasm of the muscles encircling the bronchi. This is almost instantly relieved by adrenergic drugs. A secondary process is the inflammatory system activation, which is usually slower, giving swelling and excessive mucus production by the mucous membranes. This also causes poor air passage and wheezing. Inflammation of the airways is not unique to asthma but occurs during viral and bacterial infections in all humans, particularly in those who have contracted COPD by smoking. These are much slower processes that can remain for days or weeks despite adequate treatment. This difference is important for the asthmatic patient to understand and is not stated clearly enough in my opinion. The reason is that self administered overdosing of adrenergic drugs is the most common cause of death in asthmatic attacks. It is important therefore, that the patient understands that it may not always be possible to quickly get complete relief despite the bronchospastic component is relieved. The inflammatory process may remain active for hours or days once it has been activated. When the asthma is inactive, the asthmatic patient has completely normal lung function as opposed to a patient with COPD who may otherwise exhibit very similar symptoms.

Question 3:

Did you feel that the simulation is an accurate description of asthma triggers and their symptoms?

Likert scale	Responses
Strongly Agree	1
Agree	0
Somewhat Agree	1
Neutral	0
Somewhat Disagree	0
Disagree	0
Strongly Disagree	0

Respondent	Likert Opinion	Further comments
Nurse	Somewhat Agree	See above, it would be better to show the symptoms as well as the biology behind them.
Physician/ Specialist in Anesthesiology and Intensive Care.	Strongly Agree	Yes, I strongly agree

Question 4:

Did you find the visual communication (images) of the external triggers in "Part 6" to be clearly visible and accurate?

Likert scale	Responses
Strongly Agree	2
Agree	0
Somewhat Agree	0
Neutral	0
Somewhat Disagree	0
Disagree	0
Strongly Disagree	0

Respondent	Likert Opinion	Further comments
Nurse	Strongly Agree	I liked the pictures of real allergens and the cute dog.
Physician/ Specialist in Anesthesiology and Intensive Care.	Strongly Agree	Yes, I strongly agree

Question 5:

How effective do you feel a free 3D simulation would be in informing patients and their families about what happens when someone has asthma?

Likert scale	Responses
Strongly Agree	1
Agree	0
Somewhat Agree	0
Neutral	1
Somewhat Disagree	0
Disagree	0
Strongly Disagree	0

Respondent	Likert Opinion	Further comments
Nurse	Strongly Agree	I think it would very useful but needs to include treatments.
Physician/ Specialist in Anesthesiology and Intensive Care.	Neutral	

Question 6:

Are there any final comments you would like to make?

Respondent	Further comments
Nurse	I would prefer it if the 3D model had pants on!
Physician/ Specialist in Anesthesiology and Intensive Care.	My main comments are that the anatomy of breathing seems a bit strange, with the arrows symbolizing air apparently passing into the rib cage outside of the windpipe and bronchi. I am not sure how well versed the average person is in the Latin nomenclature, maybe it wold help to mention the English words voice- box and windpipe. The main breathing muscle (80 -90%) is the diaphragm separating the thorax from the abdomen. When breathing the twin upward convexities of the cupola of the diaphragm flatten, thereby expanding the space inside the ribcage. The air is sucked into the thorax because the lungs, freely suspended inside he thoracic cavity are suction- expanded to the walls of the cavity, and lubricated by mucous membranes covering the inside of the thoracic cavity and the surface of the lungs. That is why the apparent passage of air outside of the windpipe in your pictures bothers me. If the surface of the lung is punctured (as it can be by fractured ribs or sharp instruments, or even breathing forcefully or coughing against resistance) air leaks into the normally sealed space between lungs and the thoracic wall. That will cause the lung to collapse by its own elastic force and thus the breathing movement will cease to be transferred from the diaphragm and chest wall to the lung. This can cause asphyxiation because the lung will not expand any more despite the breathing movement. (The bird of prey punctures the lungs of its prey by inserting heir claws into the ribcage when they grip the back of the animal sideways across its spine. The poor prey then dies of asphyxiation) In terms of asthma mechanisms I feel that you have understated the role of bronchospasm (the bronchial muscles encircle the bronchi. During an asthma attack they go into spasm, thereby narrowing the bronchi and bronchiolae, causing the whistling sound and the increased resistance to air passing.). This spasm can be almost instantly released by adrenergic bronchodilators (similar in action to adrenaline). The asthmatic person has no functional impairment of his breathing at all, except during an attack, as opposed to the person with chronic-obstructive lung disease (COPD), most often cause by smoking. In your simulation the emphasis is on the inflammatory mechanisms causing swelling and excess mucus production. These mechanisms similarly occur in non- asthmatic

	patients with pneumonia, COPD or bronchitis. It may take many hours or several days to normalize even with adequate medication. This is an important differentiation that will be recognized by any asthmatic patient. Thank you for letting me have a look at your work, fascinating and potentially a wonderful teaching aid.

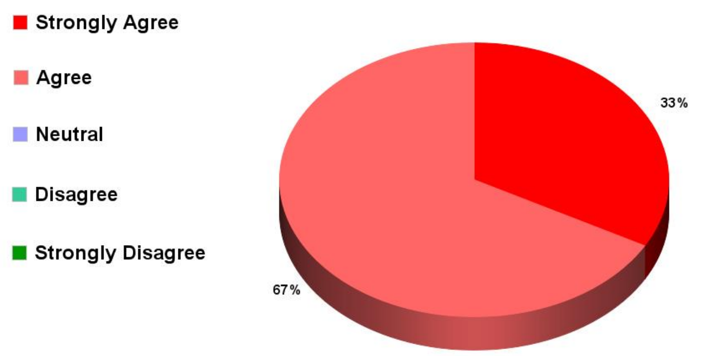
v. Questionnaire Feedback from Asthma Sufferers

This is the user testing results from the asthma sufferers.

User Survey Results: asthma Sufferers		
1) I confirm that I understand that I can withdraw at any time and confirming yes means that I agree to participate in this study.		
	Response (%)	**Responses**
Yes	100.00	6
No	0.00	0

2) Asthma, Question 1: In terms of overall presentation how easy did you find the information to understand on the subject of asthma?

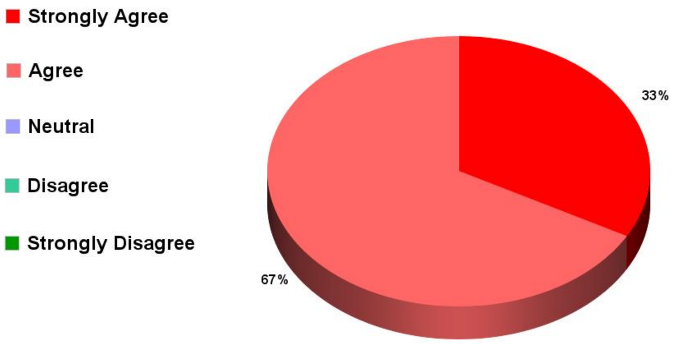
	Responses	Total
Strongly Agree	**6**	**100%**
Agree	**0**	**0%**
Neutral	**0**	**0%**
Disagree	**0**	**0%**
Strongly Disagree	**0**	**0%**



Respondent ID	Answer
11358169	Perfect, easy to understand, interesting.
11358432	Very clearly spoken and laid out, good level of detail but some key medical words could use further explanation
11479402	Well spoken, clear and easy to understand

3) Asthma, Question 1.1 Did the simulation give you enough information about the causes of asthma?

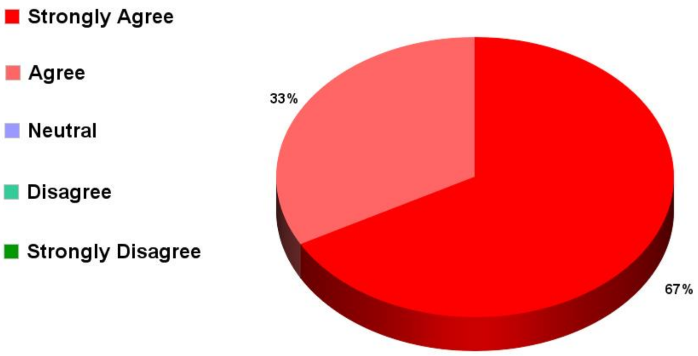
	Responses	Total
Strongly Agree	**2**	**33.3%**
Agree	**4**	**66.6%**
Neutral	**0**	**0%**
Disagree	**0**	**0%**
Strongly Disagree	**0**	**0%**



Respondent ID	Answer
11356102	Yes but the triggers section needs explanation of why or how the triggers affect the body - and should there be discussion of how to avoid / deal with these situations?
11358169	It did but it could have gone much deeper into other cause like hereditary asthma within family and how it can trigger at different stages of your life. Even talk about how asthma can actually get better over time.
11358432	List of causes were not very extensive, could have used detail on how each affects the lungs.
11479402	Yes there was enough to cover the basics of asthma and its condition.

4) Asthma, Question 1.2 Did the visual 3D presentation help you understand what happens inside a human body during an asthma attack?

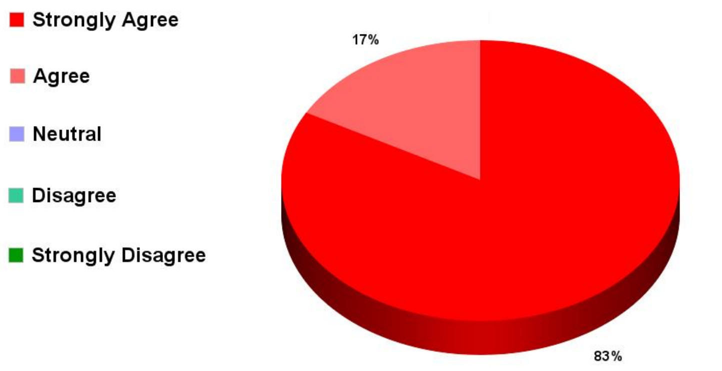
	Responses	Total
Strongly Agree	**4**	**66.6%**
Agree	**2**	**33.32%**
Neutral	**0**	**0%**
Disagree	**0**	**0%**
Strongly Disagree	**0**	**0%**



Respondent ID	Answer
11358169	Again it was good but it could have gone into the more examples of severe discomfort, can't sleep, and how it effects you more.
11358432	Very clear diagrams with useful animation to show effects of asthma attack.
11479402	I liked the way the 3D Animation helped show the air pipes close, I thought that was really interesting.

5) Asthma, Question 1.3 In terms of medical information about asthma how does this simulation compare to pamphlets?

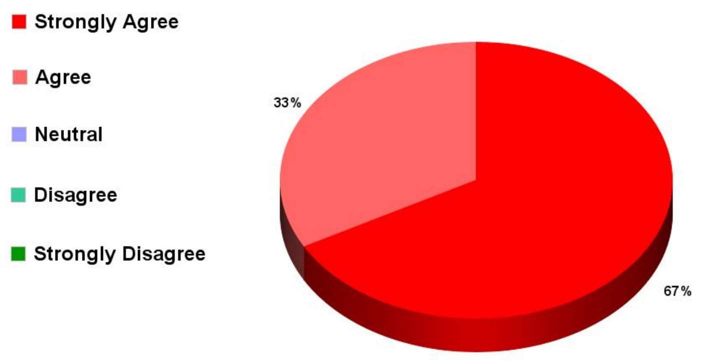
	Responses	Total
Strongly Agree	**5**	**83.33%**
Agree	**1**	**16.66%**
Neutral	**0**	**0%**
Disagree	**0**	**0%**
Strongly Disagree	**0**	**0%**



Respondent ID	Answer
11356102	Much clearer than a leaflet
11358169	Its interactive and visual more interesting than words on a paper, this help people get more engaged into it.
11358432	Far more effective, easy to understand and look through. However menu could use configuring to allow for easier exploration of the program.
11479402	Yes agree, much better for information then text.

6) External Triggers: Question 2.0 Did you find it easy to navigate to the information on “External Triggers” that can cause asthma?

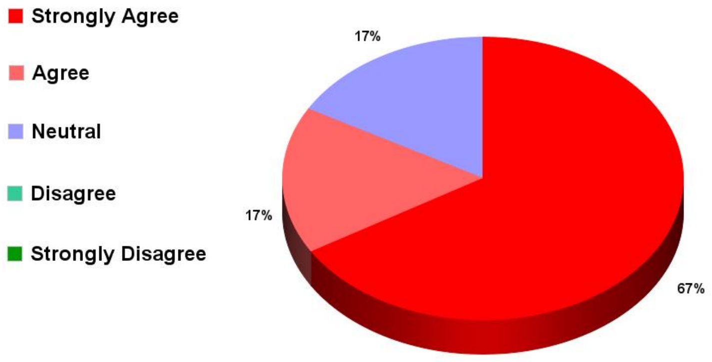
	Responses	Total
Strongly Agree	**4**	**66.66%**
Agree	**2**	**33.32%**
Neutral	**0**	**0%**
Disagree	**0**	**0%**
Strongly Disagree	**0**	**0%**



Respondent ID	Answer
11358169	Perfect and easy to accuses
11358432	Nicely laid out
11479402	Yes it was easy, very vanilla and just right for the range of people who might use this.

7) External Triggers: Question 2.1 Was the information on what irritated the lungs into having an asthma attack easy to understand?

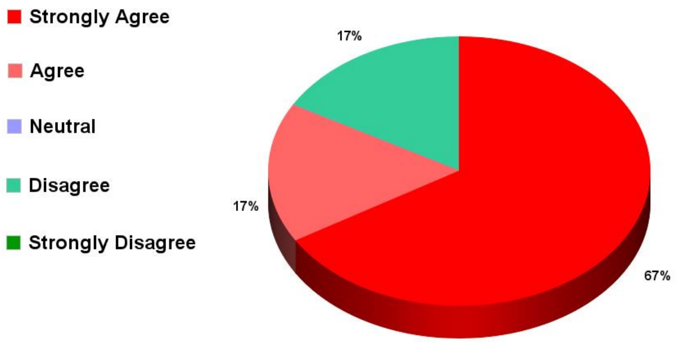
	Responses	Total
Strongly Agree	**4**	**66.66%**
Agree	**1**	**17%**
Neutral	**1**	**16.66%**
Disagree	**0**	**0%**
Strongly Disagree	**0**	**0%**



Respondent ID	Answer
11358169	It has done so, thou a bit more examples can be shown and explained such as pushing your body to hard/straining which can cause asthma attacks.
11358432	Easy to understand but lack of detail
11479402	yes I could understand the information.

8) External Triggers: Question 2.2 Did you find the visual images of the external triggers in “Part 6” (as shown in the figures below) to be visually clear enough to understand the causes of the asthma triggers?

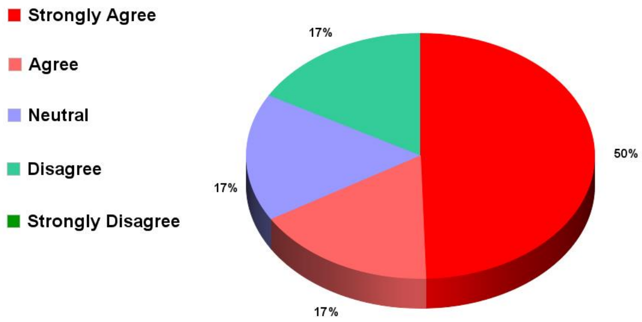
	Responses	Total
Strongly Agree	**4**	**67%**
Agree	**1**	**16.66%**
Neutral	**0**	**0%**
Disagree	**1**	**16.66%**
Strongly Disagree	**0**	**0%**



Respondent ID	Answer
11356102	Many of the images need either textual descriptors or audio to explain why or how the pictures are triggers. It is not obvious what some of the images actually represent. If the images fitted within a common template shape that would look visually more coherent.
11358169	I really liked this part as it helps identify each cause with a little picture for people.
11358432	Some detail that could have used more explanation
11479402	This was the best bit, I want more of this.

9) External Triggers: Question 2.3 Did you feel there was enough photo imagery information provided in the External Triggers section of the simulation?

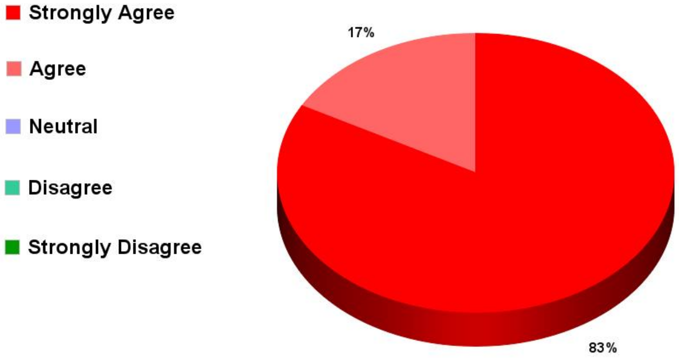
	Responses	Total
Strongly Agree	**3**	**50%**
Agree	**1**	**16.66%**
Neutral	**1**	**16.66%**
Disagree	**1**	**16.66%**
Strongly Disagree	**0**	**0%**



Respondent ID	Answer
11356102	There was perhaps too much photo imagery in this section - one image per trigger would suffice, although if there was audio commentary to explain the pictures then having multiple images makes more sense.
11358169	Needs more photos on what i explain above that has not been included
11358432	Photos could have been more scientific in areas as opposed to stock images.
11479402	All it needs is audio commentary to be added to this bit and it would be perfect.

10) Interface and Audio: Question 3.0 Was the overall usability of the simulation easy to use?

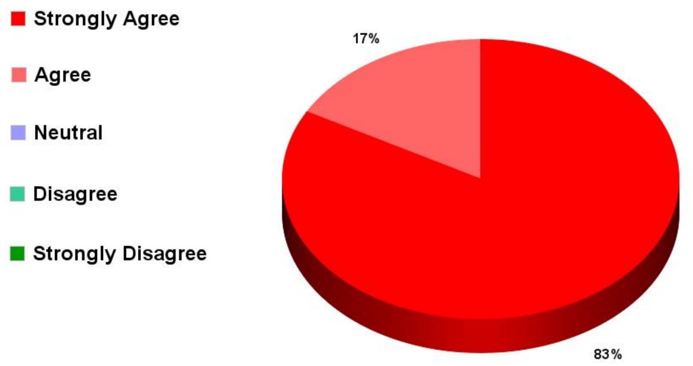
	Responses	Total
Strongly Agree	**5**	**83.33%**
Agree	**1**	**16.66%**
Neutral	**0**	**0%**
Disagree	**0**	**0%**
Strongly Disagree	**0**	**0%**



Respondent ID	Answer
11358169	it was fine
11358432	Easy to use and no confusing structure, however menu system could be improved.
11479402	Yes it was just right, to the point and gave the information needed.

11) Interface and Audio: Question 3.1 Was the animation that explained the tightening and narrowing of the airways to become even tighter easy to understand?

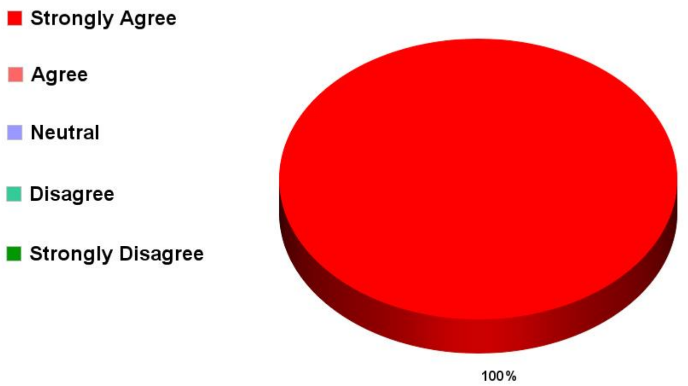
	Responses	Total
Strongly Agree	**5**	**83.33%**
Agree	**1**	**16.66%**
Neutral	**0**	**0%**
Disagree	**0**	**0%**
Strongly Disagree	**0**	**0%**



Respondent ID	Answer
11358169	easy to see and follow
11358432	Very clear animation that helped visualise the situation effectively.
11479402	Yes I understood this part.

12) Interface and Audio: Question 3.2 Did all the buttons link you into the next section without any problems.

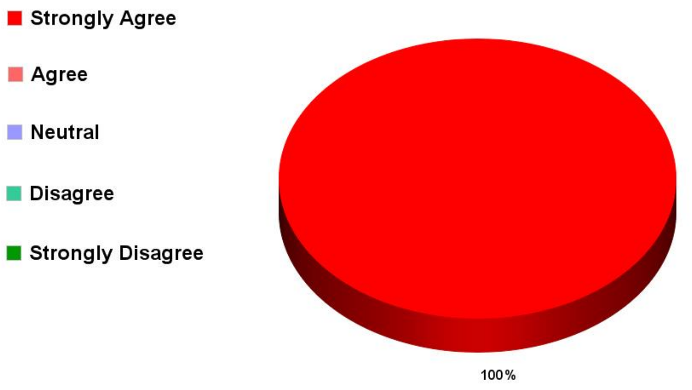
	Responses	Total
Strongly Agree	**6**	**100%**
Agree	**0**	**0%**
Neutral	**0**	**0%**
Disagree	**0**	**0%**
Strongly Disagree	**0**	**0%**



Respondent ID	Answer
11358432	No problems
11479402	It all worked fine.

13) Interface and Audio: Question 3.3 In the simulation was the level of detail appropriate enough to explain the condition of asthma?

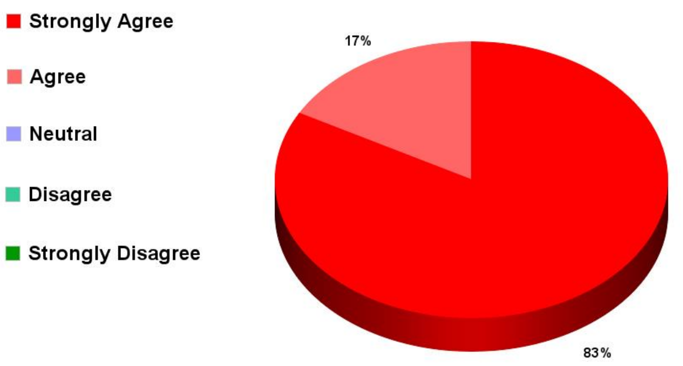
	Responses	Total
Strongly Agree	**6**	**100%**
Agree	**0**	**0%**
Neutral	**0**	**0%**
Disagree	**0**	**0%**
Strongly Disagree	**0**	**0%**



Respondent ID	Answer
11356102	Yes although an audio clip of different levels of asthma severity might have worked well with the animations of the airways narrowing. Although it would be hard to source such audio...
11358086	It was very informational. One thing I noticed that the pamphlets had but the video doesn't is prevention methods.
11358169	I believe so
11358432	Intro was thorough and clear
11479402	There was nothing missing so yes I agree

14) Interface and Audio: Question 3.4 Was the software easy to use or did you get lost anywhere and find that you could not return to the start?

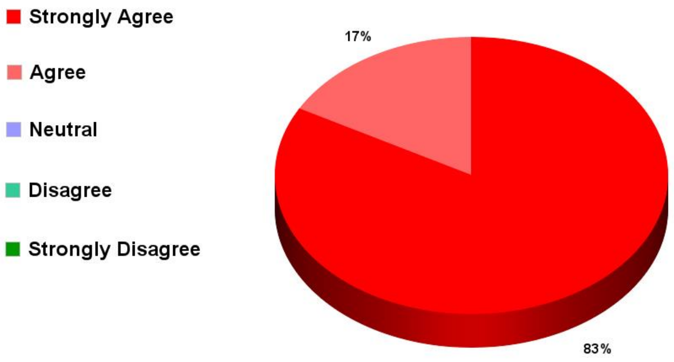
	Responses	Total
Strongly Agree	**5**	**83.33%**
Agree	**1**	**16.66%**
Neutral	**0**	**0%**
Disagree	**0**	**0%**
Strongly Disagree	**0**	**0%**



Respondent ID	Answer
11358432	Some extra steps that weren't required.
11479402	It all worked fine, no bugs.

15) Interface and Audio: Question 3.5 For the overall simulation was the audio clear and easy to understand?

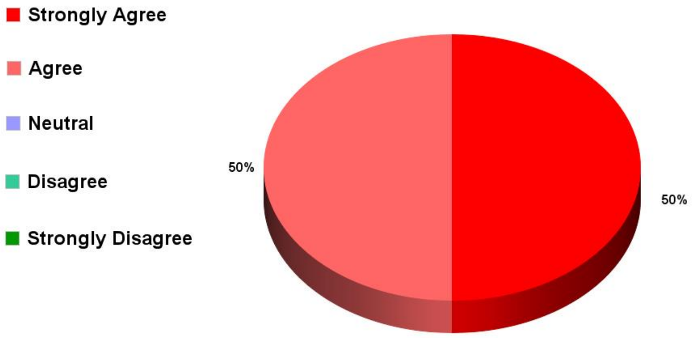
	Responses	Total
Strongly Agree	**6**	**100%**
Agree	**0**	**0%**
Neutral	**0**	**0%**
Disagree	**0**	**0%**
Strongly Disagree	**0**	**0%**



Respondent ID	Answer
11358169	some of the voice sound a tad bit muffled but most was fine to understand
11358432	Audio for the female voice was clear, some were a bit fuzzier
11479402	I thought the audio was all really clear, the female voice was best.

16) Interface and Audio: Question 3.6 For the overall simulation, do you feel there was enough audio information provided?

	Responses	Total
Strongly Agree	**3**	**50%**
Agree	**3**	**50%**
Neutral	**0**	**0%**
Disagree	**0**	**0%**
Strongly Disagree	**0**	**0%**



Respondent ID	Answer
11356102	Yes except in the triggers, where audio would've explained the images.
11358169	yes
11358432	Good use of audio information, however the triggers section had no audio
11479402	Yes

17) Are there any final comments you would like to make?

Respondent ID	Answer
11356102	Impressive work, well done!
11358169	Over all it was a really nice well rounded sim and the only thing I think it needs is some more detailed depth and explain of other triggers and cause of asthma.
11358432	Very clear and well animated. Good use of images however some more text for additional information could be useful.
11479402	This is an interesting bit of kit for information on problems and the kind of tool I would use to find out more information about health problems.

vi. Forum Threads, Q&A strategies

Community forums posts, the researcher alias is ‘Littleclaude’, the following threads are a record of my activity in community forums.

1. http://hutonggames.com/playmakerforum/index.php?topic=5140.0

2. www.polycount.com/forum/showthread.php?p=1866297#post1866297

3. www.polycount.com/forum/showthread.php?t=100182

4. http://forum.unity3d.com/threads/202292-Medical-Simulator-that-works-through-Unity-Web-Player

5. http://forum.asthma.org.uk/yaf_postsm120252_Medical-Simulator-About-Asthma.aspx#post120252

6. http://forum.unity3d.com/threads/how-to-embed-a-unity-game-into-a-webpage.86356/

7. https://www.wix.com/support/html5/wix-app-market/adding-apps-to-your-site/kb/how-do-i-add-games-on-my-2

8. https://www.wix.com/support/html5/wix-app-market/adding-apps-to-your-site/kb/how-do-i-add-games-on-my-2