Visualising Time

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Abstract

This study investigates the visualisation of temporal relationships between objects. A popular method employed for such information visualisations is the time line consisting of a single horizontal axis along which temporal events or objects are depicted at specific points or intervals. The orientation of the temporal progression along the axis line will generally coincide with the orientation of the literary writing progression of the culture and language. For example a time line visualised in a Western culture with English as its literary base will exhibit a temporal progression orientation of early/left, later/right whereas Arabian culture with an Arabic literary base will exhibit the reverse temporal progression orientation. In both cultures and languages temporal metaphor use spatial concepts to describe temporal relationships with no discourse to transversal orientation. This is reflected by never hearing the phrase "the months to the right" but rather "the months ahead". In science, Einstein showed via his special and general theories of relativity that time and space are interlinked. The scientific rationalisation of time and space along with the use of spatial concepts as temporal metaphor implies that the underlying perception of time is spatial. Information visualisations are the externalisations of our perceptions. Therefore temporal information visualisations should employ spatial visualisation techniques.

This study evaluated spatial visualisation techniques for temporal information visualisations via a web survey. The spatial temporal information visualisations used in the survey employed no temporal cues such as time or date stamps but

conferred all temporal progression via spatial cues. The findings from the analysis of the participant responses to the survey showed that spatial cues do impart temporal cues for temporal relationships.

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Chapter 1

Introduction

Information visualisation, the creation of pictures to convey and store, concepts and information, thus externalising memory and ideas, is defined by the psychologist Merlin Donald as a significant stage in the evolution of homo sapiens as it occurred without a biological evolutionary component (Gärdenfors, 2003). This defining activity has from the cave art of the late Palaeolithic era been refined via the formation of rebus, and then alphabetisation, to become writing and thus literature. Information visualisations and literature have for the last ten millennia provided avenues for the expression and storage of ideas and memories. Literature, which at first was only available to an elite few, became the dominant methodology in the last millennia due to the development of the printing press which made literature accessible to the masses (Goaman & Hyslop, 1966).

In literature, numerical data sets are organised into tables of rows and columns. William Playfair (1759-1823 C.E.) recognised that cognition of numeric tables is difficult but by externalising numeric values as spatial area via information visualisations numeric data sets could be explored, examined and understood with ease (Few, 2009; Tufte, 2001). Although the field of statistics uses tables extensively to present data and findings it has only adopted information visualisations in the latter half of the twentieth century. This late adoption was due to a long held belief that information visualisations were purely decorative with no informational benefit (Tufte). The advent of digital computing with graphical capabilities in the last quarter of the twentieth century has seen a proliferation in the production and use of information visualisations (Few). Unfortunately this increase in information visualisations has also led to a high number of deceptive information visualisations being produced (Tufte).

Information visualisations, like statistics, can be manipulated to lie and mislead. Unintentional deceptive information visualisations can occur for various reasons (Tufte, 2001). Computer based information visualisation applications rely on the skill and knowledge of the operator to select the appropriate technique for the data set (Few, 2009). The visualiser may misunderstand the data set, either the detail, context, or both, which can lead to an incorrect perception therefore the externalisation will result in an incorrect information visualisation (Tufte).

Statement of the Problem

Temporal relationships between information objects are depicted with time line information visualisations. Time lines employ a single temporal axis with information added at specific points or intervals along the axis to visualise the temporal relationship between the information objects (Wills, 2012). Temporal progression is unidirectional along the temporal axis with a left/earlier to right/latter progression being a common orientation in Western cultures, with a left to right writing progression orientation. Arabian cultures with a writing progression orientation of right to left depict time lines with a right/earlier to left/later temporal progression orientation (Weger & Pratt, 2008).

Western and Arabian cultures exhibit a commonality in temporal perception of time being non cyclic based on their Judaic, Christian, and Islamic teachings which hold with a linear time perception (Coveney & Highfield, 1990). This temporal commonality is therefore at odds with the contrasting temporal progression used in their respective time line information visualisations. There is either an underlying temporal perceptual difference or time line visualisations are not a true externalisation of temporal perception. By determining how time is perceived internally, an externalisation via an information visualisation should be coherent and complete, without restrictions imposed by culture or language.

Background and Need

When confronted with a text containing a set of events with complex temporal relationships an analyst will sketch a time line to visually assist in clarifying the chronological order and temporal associations (Kuchar, Hoeft, Havre, & Perrine, 2006). The information detail associated with temporal objects in a time line visualisation can be enhanced by annotation. However annotation can clutter the time line visualisation distracting/detracting from the contextual aspects of the temporal relationships being depicted (Wills, 2012). Time line visualisations should not be confused with time series information visualisations where the change in an attribute or attributes over time is the primary focus of the visualisation's context and detail (Wills).

Time line visualisations adhere to a one dimensional, and linear view of time, with time passing from the past to the future, on a single axis along which the temporal objects can be arranged (Aigner, et al., 2007). In literature, temporal metaphors tend to orientate time with the future in front and the past behind rather than defining it as a specific one dimensional orientation either vertical or horizontal with temporal progression orientated as up/down or left/right respectively (Santiago, Lupiáñez, Pérez, & Funes, 2007). In Western cultures, the left/right association of temporal concepts is predominant in graphs and figures which differ from front/back categorizations that often occur in colloquial language. The orientation of the temporal progression appears to be influenced by the orientation of the written word. For example, English speakers follow early/older/left and late/younger/right association, whereas Arabic speakers show the opposite pattern (Weger & Pratt, 2008).

Information visualisations are the externalisation of internal concepts however time lines that visualise temporal relationships between objects do not fully express the concept of time as reflected in language or understood by the science of physics. Cultural constructs of the literary form dictate the direction of written progression and influence the temporal progression employed restricting time line visualisations to the cultural sphere within which they are developed. Where the temporal objects incorporated in a time line visualisation are purely graphical, with no textual component, the textual rule of progression orientation of the cultural literature restricts the time line visualisation to that cultural sphere. Temporal concepts that have similar temporal spatial metaphors in different languages independent of culture should enable the externalisation of a temporal perception via spatial temporal information visualisation unrestricted by culture.

Purpose of the Study

The purpose of this study is to go back to the first principles of information visualisation based on the core homo sapien trait of externalising internal concepts and perception via visualisations; determine how time is internalised; externalise the temporal perception via visualisation; and, validate the visualisation technique with an empirical quantitative study.

Time lines are the primary visualisation technique employed to visualise temporal relationships between objects. The predominant use of a horizontal, one dimensional axis along which the temporal objects are arranged does not reflect the internal concept of time as externalised via temporal metaphor in language which is primarily spatial with no discourse as to a dominant direction. The spatial internalisation of temporal concepts is evident in a child's development and is supported by the science of physics where Einstein's theories of relativity combine space and time. Therefore information visualisations of temporal relationships between objects should employ a spatial visualisation for time.

An evaluation of the temporal information visualisation technique utilising spatial perception for time was performed through a web based survey. The survey consisted of four sections with five questions, each section employing a different information visualisation technique to depict the temporal relationship between two objects. No textual temporal cues such as dates or times were used in the visualisations ensuring that the arrangement of the objects within the visualisation provided the only temporal indicator. The first section utilised the time line information visualisation technique. The second section placed the images of the objects in a three dimensional (3D) landscape that employed the spatial cues of perspective, misting, and horizon, to emphasise depth. To eliminate any undue influence of temporal progression orientation the images were placed in a direct line receding from the observer. In the third set the images of the temporal objects were arranged as if they were hung on the right wall of a corridor or hall as viewed by the observer standing at one end with the field of view directed toward the other end. The fourth set of questions were arranged in similar visualisations to the third set but with the images appearing to be hanging on the left wall of the hall. The Internet web survey questions and visualisations are in Appendix A.

As a spatial 3D based information visualisation technique to illuminate temporal relationships between objects is not dependent on the cultural orientation of temporal progression thus allowing the construction of information visualisations that can be deployed across cultural boundaries. The comprehension of spatial based temporal information visualisations will be innate, based on the interlink of spatial and temporal concepts in a child's development, therefore reducing the textual overhead of providing temporal cues to establish temporal progression. The ready availability of media and graphical tools that enable the production of spatial 3D visualisations provides the catalyst for adopting spatial representations for temporal relationship visualisations.

Research Question

The objective of this thesis is to test the hypothesis that spatial, 3D visualisation of temporal relationships between objects is intuitive as it utilises the viewers pre-existing cognitive construct of space time that is evident in language via the use of spatial metaphor for time and is supported by the scientific view of space time espoused by both the special and general theories of relativity of Albert Einstein.

Significance to the Field

The use of 3D, spatial information visualisations to illuminate and explore the temporal relationships between objects provides a new direction for information visualisation research. The use of 3D imaging techniques set new challenges for determining, analysing and defining rules to achieve balance between context and detail. For example, interposition which can enhance depth of view perception there by increasing context will reduce detail. When detail is reduced by interposition to the point that the information object loses its identity the context is then diminished. Another area that needs investigation is depth of field where detail diminishes as the information object recedes from the observer. Other aspects of 3D image presentation that require research are field view, which relates to width of view and foreshortening of depth perspective, the need and use of depth cues such as horizon and misting, the placement of the camera, and point of perspective above the plane of view.

Definitions

2D	Two dimensional, lacking in volume and/or depth (Hanks, 1979).
3D	Three dimensional space (Hanks).
Atmospheric perspective	Reduction of contrast and change in colour resulting from the scattering of photons in the atmosphere. The effect produces a contrast and colour gradient that enhances perspective depth (Braunstein, 2005).
GNOME	Acronym for GNU Network Object Model Environment. An X Windows desktop environment for systems using the Unix/Linux operating system. GNOME is distributed as open source and is part of the GNU Project (Pfaffenberger, 2003).
Gradient perspective	A regular pattern that is foreshortened (Braunstein).
GNU	Acronym for GNU's Not Unix. The GNU Project, created by the Free Software Foundation, is an open source version of the Unix operating system (Pfaffenberger).
HTML	Hypertext Markup Language. Tags in a World Wide Web page that direct how the content of the file is displayed (Stevenson, 2010).

Internet	A global computer network (Stevenson).
Interposition	Interruption of the contours or surface texture of a background object by foreground object (Braunstein).
Linear perspective	The convergence of parallel lines that extend into the distance thus inferring perspective depth (Braunstein).
MRI	Abbreviation for Magnetic Resonance Imaging (Stevenson).
Occultation	The disappearance of one object as it moves out of sight behind another object (Hanks).
Planar	Relating to or lying in one plane (Hanks).
QR Code	Abbreviation for Quick Response Code. A QR code is a two dimensional graphic code, similar to a bar code (Crompton, LaFrance, & van 't Hooft, 2012).
Rebus	The use of pictures to represent syllables (Hanks).
Temporal	Relating to time (Hanks).
URL	Abbreviation for uniform (or universal) resource locator which is a World Wide Web page address (Stevenson).
Web	Abbreviation for World Wide Web (Stevenson).

Web cookie	Small files that a website places on a web users hard drive that contain details the web site can refer to in future visits to determine past activities (Tanenbaum & Tate, 2008).
World Wide Web	Interconnected hypertext linked documents on the Internet (Stevenson).

Limitations

Evaluation of visualising temporal relationships between objects utilising spatial visualisation techniques was conducted via an Internet web survey. During the design and construction of the survey the use of real world object images was recognised as an issue. The survey participants might have specialist prior knowledge in regards to the subject pertaining to the temporal objects portrayed in the visualisation, or they might gain temporal cues from the background of the image. To counter this specialist prior knowledge, each visualisation concerned a unique subject selected from a wide variety of subjects including antique dolls, hydro dams, Greek vases, thoroughbred livestock, early twentieth century glass perfume bottles, to arcade video games, and flowers. Images of the temporal objects selected had neutral backgrounds with no temporal cues. Another concern was the ability to search for the answers to the questions as the survey was to be conducted on the Internet therefore participants would have access to Internet search engines. An Internet search engine test was included in the selection process of each subject and question with the size and content of the result pool evaluated to establish the ease, or lack of, in determining an answer to a question. The grouping and order of the four information visualisation techniques were also recognised in the construction phase of the web survey as an issue as it may lead to training of the participant. This issue was addressed by randomising the order of the last few questions and first few questions of adjacent information visualisation technique question groups. The last two visualisation technique question groups were similar, therefore all the questions of these two question groups were randomised together.

Ethical Considerations

The evaluation of visualising temporal relationships between objects utilising spatial visualisation techniques was conducted via an Internet web survey requiring human participants therefore an application for ethics consent was required from the Ethics Committee, Faculty of Computing and Mathematical Sciences, under the Ethical Conduct in Human Research and Related Activities Regulations. The documentation submitted as the application for ethical consent and the letter conferring ethical consent for human participation in the Internet survey is included in Appendix B.

Thesis Structure

This thesis consists of five chapters and supporting appendices. Chapter 1 comprises the introduction, description of the problem, background, purpose of study, research question, and the significance of the study. Chapter 2 is a review of literature on existing and proposed temporal visualisation techniques, information visualisation, temporal conceptualisation and perception, and the scientific view of time. Chapter 3 documents the construction and execution of the Internet web survey undertaken to evaluate visualising temporal relationships between objects utilising spatial visualisation techniques. Chapter 4 is an analysis of the participants responses' to the Internet web survey. Chapter 5 discusses the analysis of the web survey and conclusions drawn from this analysis. It also covers future areas of research including expanding on this study, as well as defining and refining aspects of visualising temporal relationships between objects using spatial visualisation techniques.

Chapter 2

Topics that Underpin Research Into Visualising Time

This literature review explores three topic areas. Two relate to the underlying concepts that form the thinking that led to the formulation of the hypothesis. The first topic covers information visualisations, how they define us, and their history. The second topic is the perception of time, which depending on cultural and/or religious reference can vary widely; the influence and/or reflection of temporal state and progression in language; to the scientific view of time which has been an instrument of movement measure, an all encompassing uniform envelope, and now considered flexible and integrated in space time. The last topic covers existing visualisation techniques and current discussions seeking to define a temporal visualisation taxonomy.

Information Visualisation

The psychologist Merlin Donald defined three stages in the evolution of thought which can be linked to different levels of communication. The first stage, the mimetic, is the ability to bodily enact or mime an event, assisted by the biological expansion of the brain allowing the development of enhanced coordinated control of limbs. The second stage, mythic, occurs with vocalisation which allows expression to develop via story or myth telling, aided by the biological evolution of the larynx. The third stage is externalization of memory, via the creation of pictures, then writing, to convey and store ideas and information. The externalization of ideas, concepts, and knowledge through information visualisation is significant as it has occurred without a biological evolutionary component (Gärdenfors, 2003). Homo sapiens began storing symbols from the inner world of their minds externally with pictures in caves during the late Palaeolithic (Sieveking, 1979). These visualisations of animals and humanoids have been interpreted as records of hunts depicting prey and strategy (Goaman & Hyslop, 1966). However the majority of these visualisations are overlaid with geometric shapes, similar to phosphenes. Phosphenes are subconscious images generated in the neural cortex when the mind enters a trance induced state. Phosphenes are therefore innate, thus explaining their commonality in Palaeolithic art across widely disparate geographical locations such as Australia, Africa, and Europe. J. D. Lewis-Williams has concluded that Palaeolithic art is the work of shamans externalising phosphene adulterated images that they experience while in trance (Bahn & Vertut, 1988).

Palaeolithic information visualisations used in conjunction with story and myth telling developed into picture writing, the earliest form of writing, where a set of images is used to assist in the retelling a story, a practice still used by Australian Aboriginals (Goaman & Hyslop, 1966). Pictures evolved into signs or memory aids to assist information storage and dissemination, the practice of mnemonic writing. Mnemonic information visualisations can be abstract such as the quipu knotted cords, used by the Incas, or tally sticks to verify debts used in Britain as financial records until 1834 C.E. (Goaman & Hyslop). Denis Schmandt-Besserat has claimed that thousands of small clay objects, “tokens”, used to record trade transactions recovered from archaeological digs from Palestine to Iran, and dating back to 8000 B.C.E. combined with the clay envelopes on which the tokens were impressed and then sealed within are the starting point for cuneiform writing (Daniels, 1996). Ideographs are pictures of an object but applied to mean something else or an idea, for example an image with three suns represents three days (Goaman & Hyslop). The Shang dynasty (ca. 1200 B.C.E.) employed a logographic/ideographic writing system where each character stands for a single word, the earliest form of written Chinese (Boltz, 1996). Chinese writing is a complex set of ideographs that have developed over time with each object, idea, and word, having its own unique image. Japanese writing is derived from Chinese but the ideographs have been simplified and can represent a syllable so that several ideographs can be grouped together to form a word to represent an object or idea. Using ideographs as syllables reduces the number of different ideographs required to produce a text (Goaman & Hyslop). Phonetic writing uses a rebus, pictures to represent sounds, it is exemplified by Egyptian hieroglyphs that developed prior to the First Dynasty (ca. 3100 B.C.E.) and in use for four thousand years until around 1000 C.E. (Ritner, 1996). Repeatedly simplifying the picture used for a sound led to a basic, simple to render symbol, and as the number of unique sounds used in a language is small, the symbol set to represent those sounds is small giving rise to alphabets (Goaman & Hyslop). The externalisation of memories and ideas via writing revolutionised communication allowing the sharing of information without the need to meet face to face. Writing also made it possible to store information therefore creating pools of knowledge that could exceed what one individual could master and yet be accessible to all (Schmandt-Besserat, 1996).

The development of information visualisation techniques enabled the dissemination and storage of information beyond the temporal concurrence of the communicants (Gärdenfors, 2003). These visualisation techniques, refined to a rebus and then to an alphabet enhanced further the communication and storage of information (Goaman & Hyslop, 1966).

However the effectiveness of writing for information dissemination is dependent on the literacy attainment of the communicants. When illiteracy is the norm, information visualisation is the primary communicative and information storage technique. This can extend to visualisations being used to increase accessibility to a written work (Hedgecoe, 2006). In 645 B.C.E., Ashurbanipal, the King of Assyria, wishing to increase his stature utilised the literary heroic story of Gilgamesh. Ashurbanipal had a frieze of the story created on the wall of the throne room of his great palace at Nineveh with himself as the central character. Ashurbanipal went on to create the world's first complete visual story depicting his victory over the Elamites at the Battle of Til Tuba (Hedgecoe). A complete example of a visual story can be viewed today in Rome, where Trajan's Column erected in 100 C.E., still stands. The column, 35 metres tall, commemorates Emperor Trajan's war against the Dacians. The scenes spiral 23 times around the column depicting the saga over a visual length of 200 metres (Bell, 2007).

The world's first empire stretched from the Mediterranean to India in the east ruled by the Persian king Darius the Great (ca. 500 B.C.E.) Consisting of multiple nations and dozens of different languages, the empire could not be maintained cohesively by military might so Darius adopted a new political approach offering peace and co-operation. In the capital city, Persepolis, Darius, following the example of Ashurbanipal, utilised pictorial visualisations of this political stance showing Darius as a benevolent ruler over a happy and content citizenry. However the size of the empire limited the number of citizens who could visit and witness the visual representation of this political order. To solve the limited access to these political visualisations Darius adopted the image of the bowman, a familiar image to all Persians. To the Persians, the archer was symbolic not only of military prowess but of wisdom and leadership. The good archer had a sense of balance and control, qualities that were central to the concept of kingship developed by Darius. To distribute this image Darius had it struck on the coinage of the empire thus creating the first political logo. When Alexander the Great defeated the Persians in 350 B.C.E. he recognised that to rule the empire in peace he must use the same information visualisation channels and substituted his portrait for the symbol of Darius on the coins (Hedgecoe). Religious leaders also employed information visualisation as a communicative channel for their illiterate congregation (Kempers. 1994). Ringbom (1965) illustrated this utilisation of information visualisation via the words of Pope Gregory the Great (590-640 C.E.) (as cited in Kempers).

> It is one thing to worship a picture, but it is another thing to be taught by the story conveyed in the picture what to worship. For words teach those who can read; pictures show the same to those who cannot read, but only see, so that even the ignorant can learn from pictures whom they should follow; pictures enable the illiterate to read. (P. 21)

By direct patronage of the arts and indirectly by taking a keen interest in patronage by the laity, the Church of Rome attempted complete control of communication by image. This control included trials of both patrons and artists by the Inquisition for subject matter that was not of the sacred (Kempers). The Church also had a strong interest in cartography. The laity were fascinated as to where the places of the Bible were in relation to each other but also to their locale. Establishing a spatial association added credence to the information disseminated by the Church (Black, 2003). Unlike patronage of the arts, cartography was not controlled by the Church as there were no biblical edicts on spatial representations (Bagrow, 1964).

The initial use of the information visualisation technique of cartography is difficult to establish. However it has been noted that primitive peoples of the world in the present day, with no developed literary communicative form, have an innate ability to render accurate presentations of the area in which they reside depicting the relative position of localities and distances, usually recorded in units of time to travel to the different localities (Crone, 1978). Therefore it can be assumed that cartographic information visualisations were developed in conjunction with early information visualisation techniques (Crone). Rock carvings depicting plans of livestock pens and paths to grazing locations coinciding with the development of agrarian societies 10,000 years ago are the earliest known examples of cartographic visualisations (Short, 2003). Clay tablets containing impressions of maps depicting the local topography and the heavens have been found in Assyria (ca. 3800 B.C.E.) and Babylonia (ca. 500 B.C.E.) (Crone). Mesopotamian maps (ca. 1500 B.C.E.), again on clay tablets, record the estates of the political and religious elite along the curve of the river with irrigation canals separating different estates. Following the example of using a unifying image developed by Darius and employed by Alexander, Greek coins (ca. 300 B.C.E.) show cartographic images of the political sphere of influence in which they were minted (Short). In Egypt, texts describe how geometrical methods were used to measure land so property boundaries could be re-established after Nile floods. Although none of these actual land records survive to establish if in fact they were maps, maps were known and used, as papyrus maps of the nether world have been found, placed in tombs to guide the dead (Crone). Map, the common term for a cartographic work, is derived from the Latin mappa, meaning cloth (Short). The use of flexible materials for maps, such as cloth or birch bark as used by the natives of Siberia and North America, aided in the convenience for transportation and manipulation for viewing. However the lack of durability of such materials explains the limited number of examples that exist to this day of early cartographic information visualisations (Crone).

The increase in literacy has seen the written word become the dominant information storage and dissemination technique with numeric data organised into tables of columns and rows. Tables of data are known to have been developed with writing in Egypt with the oldest known European example dating between 100 and 200 C.E. (Few, 2009). René Descartes (ca. 1600 C.E.) invented the two dimensional graph as a visual method to perform quantitative calculations (Few). William Playfair (1759-1823 C.E.) recognised the limitations of tables as written numbers must be cognitively processed one at a time, which is slow and held in memory, and this quickly becomes difficult as the size of the table or data set increases. Playfair realised that by externalising numeric cognitive processes and memory by representing numbers collectively as graphs, data sets could be explored, examined, and understood with ease (Few). Playfair stated that information gained from a table containing data is soon lost where as a graphical representation of the data will be retained and understood. Playfair developed nearly all the fundamental numeric information visualisation techniques, with the objective of using this “linear arithmetic” to replace tables of numbers and thus allow greater exploration and examination of data sets (Tufte, 2001). Playfair's graphs mark a major milestone in the history of information visualisation and the start of the visualisation of time series data sets (Wills, 2012). Playfair repeatedly compared his charts to maps (Tufte). This correlation of information visualisation of data sets to spatial representations and cartography is emphasised by the title of his first published work *The Commercial and Political Atlas*. An example of combining cartography and spatial representation of data sets is Minard's map of Napoleon's march on Russia. Created in 1861 C.E. it combines time series, with temperatures, area to represent the number of men, geographical location, and colour for direction of movement (Wills).

The basis of information visualisation is the externalisation of the internal perception of the data set. For an information visualisation depicting temporal relationships between objects we must look at how we perceive time.

Temporal Perception

The philosopher Augustine of Hippo (354 - 430 C.E.) meditating on time stated; What then is time? If no one asks me, I know what time is, but if I try to explain it to another, I do not know (Teske, 1996). This implies that time is an internal concept unique to the individual (Ornstein, 1969). Plato (428-328 B.C.E.) based his philosophy of time on process, in particular, the regular celestial revolution whereas his student Aristotle viewed time as a product of motion to explain how objects could move at different velocities while time retained a constant pace (van Fraassen, 1970). The Aristotelian concept of time held to be true for almost two millennia, is based on the observation that the spatial relationship between two objects can be observed outside the context of time however time cannot be observed without a change in motion of the objects in space. Therefore this means that time is a product of motion (Elton & Messel, 1978). Conversely if all motion ceases, then time ceases which is illogical leading Isaac Barrow (1630-1677 C.E.) to reject the Aristotelian concept of time. Barrow instead depicted time as an infinite container equivalent to the infinite container of space allowing the relationship between two objects to be described in either context thus setting time independent of motion. Sir Isaac Newton, a student of Barrow, remarked, infinite and absolute space and time are independent (van Fraassen). To describe the relationship between two objects in time, time itself must be measured. The measurement of time first began with the observation of natural processes such as the revolution of the sun (Janich, 1985).

The advent of the calendar is tied to the development of agriculture (ca. 8000 B.C.E.). In Egypt, where agriculture depended on the flood of the Nile, the year with its three seasons, flood, sowing (winter) and harvest (summer) was divided into twelve months (Janich). Defining the days on which religious observances occurred required calendars of greater accuracy. This was achieved by defining base line dates via astronomical events that required temporal measurement outside the confines of the solar day. This led to the development of water clocks as chronometers (ca. 1580 B.C.E.). The draining of a container to define a temporal period is known to have preceded this date to limit court speeches where the gravity of the issue dictated how much water was placed in the receptacle and thus the length of the speaking time (Janich). Time keeping has also employed the burning of segmented candles and knotted rope (Ornstein, 1969). Villard de Honnecourt developed a weight driven device with an escapement mechanism, around 1240 C.E., that rotated a figurine of an angel so that it always faced the sun, thus creating the first mechanical clock. Clocks increased in complexity with automata, chimes, and alarms. By 1400 C.E. the reduction in the size of the mechanisms brought about the development of watches with a temporal accuracy of plus or minus fifteen minutes a day. In 1657 C.E. Huygens applied for a patent for a pendulum clock. In 1761 C.E. John Harrison solved the longitude problem with his watch, the H4, that lost only 15 seconds on a five month sea voyage from England to Jamaica (Janich).

Temporal metrology employs cyclic scales reflecting the solar rotation of days and nature's organic rhythms of seasons. The cyclic precession of the heavens led the Greek philosophers, who looked for order amongst the patterns of nature, to view the heavens as a great circle, perfect, unbroken, an order that time must also follow (Coveney & Highfield, 1990). Societies and religion have encompassed temporal cycles in reincarnation and rebirth. However cyclic time cannot hold with succession. If event *A* is followed by event *B*, followed by event *C*, event *A* must precede event *C*, however if one follows a temporal cycle, event *A* must follow event *C*. Societies and religions that identify unique events of importance such as Judaic, Christian, and Islamic teachings which hold with a linear time perception, require non cyclic time, as each relies on the uniqueness of an event that cannot be repeated as the centre of their belief systems (Coveney & Highfield).

The use of spatial metaphor for temporal description is evident in the Latin root tempus, which gave rise to the English word time, the French temps, and the Italian temp, with its meaning of 'space marked off' (Casasanto, Fotakopoulou, & Boroditsky, 2010). Biblical Hebrew uses a spatial metaphor for time that places the past in front as it is seen and known, whereas the future is behind, unseen and unknown. This spatial temporal perception and orientation is a lingual metaphorical commonality of the period and is found in languages such as Sumerian, Akkadean, and Egyptian (Newman, 2009). Aspects of this spatial temporal orientation still persist in Modern Hebrew however the orientation is increasingly reversing to the future lying before one and the past behind as the political narrative focuses on facing the unknown and the challenges it presents. The strength of this metaphoric spatial temporal orientation reversal is dependent on the extent of the differentiation of the modern language from its historical roots (Newman).

The English spatial metaphor for temporal description exhibits a strong association between a temporal progression orientation and a written progression with the older/left and the younger/right (Santiago, Lupiáñez, Pérez, & Funes, 2007; Weger & Pratt, 2008). The early/left, later/right, progression orientation extends beyond temporal metaphor to temporal objects. Experiments have shown that temporal objects such as the names of prominent film actors separated by five decades in popularity can be sorted with a high correlation of the 1950s/left and present/right (Weger & Pratt). The performance of cognitive temporal recognition is higher, determined by faster responses under experimental conditions, when spatial orientation equates to written progression orientation (Santiago et al.; Weger & Pratt). The equating of a progression orientation is also evident in time line and time series information visualisations where left to right orientation is commonly used to depict temporal progression for English writers. The reverse orientation, right to left, is exhibited by Arabic writers (Santiago et al.). In lexical terms, a spatial metaphor does not reflect the progression orientation of written language. A lexical spatial metaphor for temporal description employs every axis including up/down and forward/back. However the transversal axis, left/right, is in the minority as the expression “the coming month” is never lexically referenced as “the rightward month”. Conversely, in signed language temporal progression employs only the transversal axis (Santiago et al.).

Spatial gesture to depict or emphasise temporal narrative uses either sagittal, the body's front to back axis, or the transversal axis across the body. Sagittal temporal gestures used by Neapolitan speakers refer to the past by gesturing over the shoulder, the present by pointing down, and the future by circular forward movements of the index finger. Transversal temporal gestures involve chopping with one hand, or blocking with two in either a left or right progression (Cooperrider, & Núñez, 2009).

The linguistic feature, fictive motion, that attributes a verb to static spatial objects, for example, "the picket fence ran around the house", is also applied to temporal description as shown in, "the meeting ran until lunchtime" (Matlock, Ramscar, & Boroditsky, 2005). Temporal fictive motion emerged as a research path in a study evaluating non lingual progression orientation priming of responses to ambiguous temporal questions. The study method used images to induce a fictive motion orientation. After viewing an image, participants then answered a written temporally ambiguous question. It was found that temporal progression orientation could be influenced by viewing images that induces fictive motion (Boroditsky, 2000). In the study, one of the progression orientation images was designed to be ambiguous with three widgets placed in perspective in a spatial landscape. Of the 24 participants, 95.8% responded with the same temporal orientation contrary to the expected outcome that no influence should occur. This raises the question of whether the relationship between time and space can be generalised (Matlock, et al. 2005). However it could be that the image did have an orientation in depth, and that incorporating a fully 3D spatial construct the image strongly imparted a progression orientation.

Time is a commonality as is evident by the use of spatial metaphors across multiple cultures and languages, and between our perception, intellectual, and emotional experiences. Psychology, the study of the behaviour and mental processes, broke away from philosophy in 1879 C.E., with time being one of the first experiences investigated. Theoretical investigation of time and experimental examination of duration led to an early schism in the pursuit of understanding the perception of time (Ornstein, 1969). The experimental analysis of duration endeavoured to find a time organ, or sense of time, similar to a migratory bird's sense of the earth's magnetic field; the theoretical path followed the concept that time is the perception of the individual (Ornstein). In his study of child development, from 3 to 6 years of age, Piaget claimed that the concept of time is tightly bound with the child's spatial development (Piaget, 1969). For a child, the order of temporal succession is linked to the spatial order of movement along a path, so when non identical paths of movement or different velocities are observed that cause changes in the spatial order the temporal concepts of before and after are corrupted showing the dependence of temporal cognition on spatial conception (Piaget). A link between duration and spatial extent has been experimentally established with tone duration and length of a line, easily and precisely associated. A temporal spatial association of duration and line length is present in 9 month old infants prior to language development showing that the temporal spatial association is developed before culturally driven linguistic temporal metaphors (Srinivasan & Carey, 2010). Temporal spatial association is asymmetric, with cognition of temporal duration depending on spatial extent but not the reverse with temporal inferences having no influence on spatial cognition. The dependence of spatial input into temporal cognition extends to irrelevant spatial cues being incorporated into temporal cognition (Casasanto & Boroditsky, 2008). Asymmetrical temporal spatial association is evident in kindergarten and elementary school aged children who reflect the same cognitive processes as adults including the inability to ignore irrelevant spatial inputs (Casasanto, Fotakopoulou, & Boroditsky, 2010). Patients with right hemisphere brain damage exhibit spatial cognitive distortion in tandem with temporal cognitive distortion indicating a co-localisation of cognitive function. Neuroimaging brain activity of healthy volunteers via MRI shows the posterior parietal cortex in the right hemisphere is the centre of spatial and temporal cognition (Oliveri, Koch, & Caltagirone, 2009).

In his study of matter and its motion through space and time, Einstein (1879-1955 C.E.) abandoned the concept of absolute space where objects are described by their location with a construct where an object's location is described by its relative position to other objects. Likewise, Einstein abandoned absolute time where events are referenced by universal time, for events that take their temporal description by their relative time to other events (Barnett, 1949). Einstein's General Relativity states that there is no fixed interval of time. If person A in New Zealand talks to person B in London via telephone and it is evening in New Zealand it is early morning in London and both are considered to be talking at the same time as their clocks are tied to the rotational period of the Earth. However if one was to try and communicate with a distance star 16 light years away, the message would take 16 years to reach the star and a further 16 years for a reply. But more importantly, what we are seeing is a ghost of that star as it was 16 years ago, as it may not even exist now but is still visible here on earth (Barnett). Likewise, two events cannot occur simultaneously as the spatial separation incurs a temporal separation (Durell, 1926). The interdependence of space and time is depicted in the Minkowski space-time diagram, Figure 1. Minkowski space-time diagrams employ a relativistic unit of $c=1$ so that for each unit along the temporal axis (*t*) a photon emitted from the event (*E*) travels a spatial unit. This depicts the speed of light, as a line bisecting the temporal and spatial axis at 45° forms a light cone. An observer moving at the speed of light would reside on this line with the effect that the event would appear unchanging. In Figure 1, the observer (*O*) resides on a world line with a velocity less than the speed of light therefore the event is observed as changing but with a temporal delay of *dt* (Black, Gopi, Wessel, Pajarola, & Kuester, 2007; Jonsson 2005).

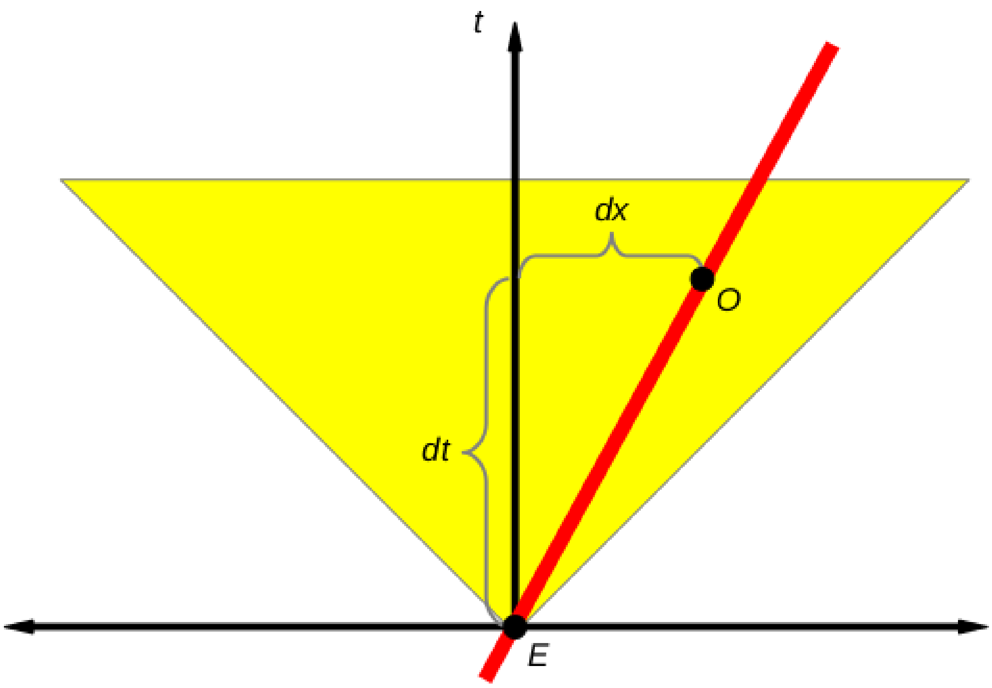

Figure 1. Minkowski space-time diagram.

Time Line Information Visualisation

A common information visualisation technique to depict the temporal relationship between two objects is the time line. Time lines visualise time in one dimension and add information at specific points or intervals along the line to visualise the temporal relationships between information objects (Wills, 2012). When confronted with a text containing a set of events with complex temporal relationships, an analyst will sketch a time line to visually assist in clarifying the chronological order and temporal associations (Kuchar, Hoeft, Havre, & Perrine, 2006). The use of time lines for visualising temporal relationships can be traced back to Joseph Priestley (1733-1804 C.E.) who created a time line chart that visualised the life spans of famous people from 650 B.C.E. to 1 C.E. along with other time lines as visual aids for his popular lectures on history (Wills).

Temporal objects depicted with time lines can be categorized into two classes, either a time point, or time interval, where a time point represents an instance in time, and a time interval is a time point with an additional extent defined either by a terminating time point or a duration (Aigner, Miksch, Müller, Schumann, & Tominski, 2007). Time line visualisations should not be confused with time series information visualisations where the change in an attribute or attributes over time is the primary focus of the visualisation's context and detail (Wills, 2012). The information detail associated with temporal objects, or time points, in a time line visualisation can be enhanced by annotation. However annotation can clutter the time line visualisation detracting from the contextual aspects of the temporal relationships that are being depicted (Wills).

Time line visualisations adhere to the one dimensional, linear, view of time, with time passing from the past to the future, providing a single axis along which the temporal objects can be arranged (Aigner, et al., 2007). In literature, temporal metaphors tend to orientate time with the future in front and the past behind rather than defining it as a specific one dimensional orientation, either vertical or horizontal, with temporal progression orientated as up/down or left/right respectively (Santiago et al., 2007). In Western cultures, left/right association of temporal concepts that are predominant in graph and figures differ from front/back categorizations that often occur in colloquial language. The orientation of the temporal progression appears to be influenced by the orientation of the written word. For example English speakers follow early/older/left – late/younger/right association whereas Arabic speakers show the opposite pattern (Weger & Pratt, 2008). The concept of temporal progression orientation in the graphical form is omnidirectional and is not reflected back as a concept in literature or linguistic dialogue with the "past month" referred to as the "left month" or the "approaching month" as the "right month" (Santiago et al., 2007). Literature and linguistic temporal metaphors extend the concept of time to also being environmental and all encompassing with phrases such as "in these times" and "there comes a time" (Torre, 2007).

Events that occurred early in the twenty first century have brought about an increased focus on intelligence analysis of event based information. Large literary data sets containing multiple temporal events requiring analysis have highlighted the difficulties of temporal event identification, sequencing, and visualisation. This has resulted in the development of numerous time line applications such as

TimeML and DAML-Time, each with their own visualisation techniques to represent temporal objects. To bring cohesion to the field a discussion needs to commence to establish an understanding of temporal perception, temporal taxonomy, and visualisation techniques (Aigner, Miksch, Müller, Schumann, & Tominski, 2007; Kuchar, Hoeft, Havre, & Perrine, 2006). Temporal primitives of time points and time duration need to be recognised as having different temporal properties that define when and how they can be used to establish temporal relationships and temporal patterns. Figure 2 demonstrates the limited temporal relationships of 'concurrent' and 'sequential' that can be visualised with time point data objects (Aigner, et al., 2007).

Figure 2. Time point temporal relationships.

Time duration or time points with extents can be visualised with additional temporal relationships depicting partial concurrence, sub concurrence, concurrent start, and concurrent completion, Figure 3 (Aigner, et al.).

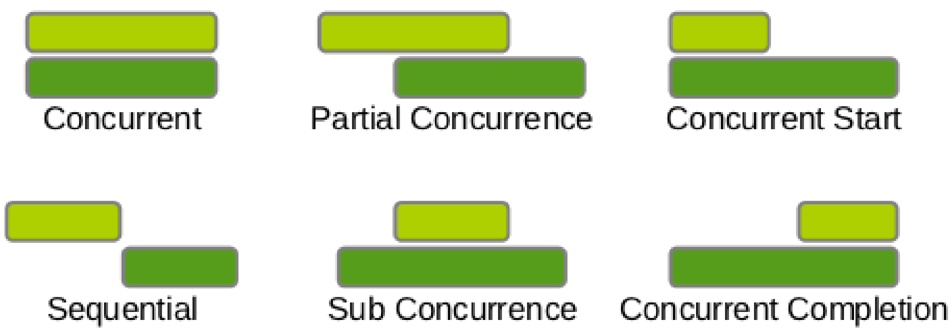

Figure 3. Time duration temporal relationships.

Temporal flow can be linear, cyclic, or branching, as shown in Figure 4. Temporal flow can be emphasised by directional connection cues between temporal time points. Graphing techniques can be used to visualise flow (Aigner, et al.).

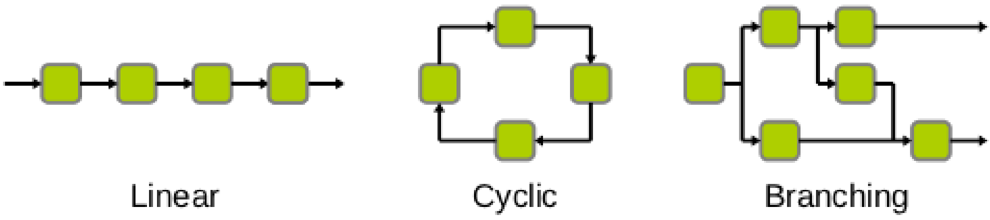

Figure 4. Temporal flow.

Visualisation of temporal events with unclear or loosely defined time points can be achieved by the use of temporal containers with concave boundaries representing approximated time points (Kuchar, et al., 2006). Framed temporal objects allow the visualisation of temporal periods within which an event occurred, shown in Figure 5.

Figure 5. Temporal events with unknown elements.

Summary

Temporal perception is internalised as a spatial construct as reflected in language by the use of spatial metaphors for temporal descriptions and validated by the science of physics which through the theories of Einstein tie temporal with spatial into a single space time continuum therefore information visualisations that externalise temporal perception should utilise spatial representations.

Information visualisations are the externalisation of internal concepts, however time lines that visualise temporal relationships between objects do not fully express the concept of time as it is reflected in language or understood by the science of physics. Cultural literary constructs dictating the direction of written progression influence the temporal progression employed restricting time line visualisations to the cultural sphere within which they are developed. Where the temporal objects incorporated in a time line visualisation are purely graphical, with no textual component, the textual rule of the cultural literature restricts the time line visualisation to that cultural sphere. Temporal concepts that have similar metaphors in language independent of culture enable the construction of temporal information visualisations unrestricted by culture.

Chapter 3

Research Survey

To evaluate temporal perception and its application in temporal information visualisations this study followed a quantitative model using a survey. The survey compared the existing temporal information visualisation technique of a single horizontal axis time line and three spatial temporal information visualisation techniques. The three spatial temporal visualisation techniques consisted of one pure 3D visualisation using an environment consisting of a plane with a horizon as spatial cues while the remaining two techniques employed 3D visualisations incorporating a single linear temporal line for temporal progression. This chapter describes the processes and resources used to design and execute the survey.

Setting

The survey was conducted on the Internet as a web based survey. Participants required access to a web browser to partake in the survey. The web survey utilised standard HTML ensuring a consistent and identical presentation of questions independent of the graphical web browser employed by the participant. The web survey was tested on the most popular web browsers, Microsoft Internet Explorer, Google Chrome, Safari, and Mozilla Firefox, to ensure question presentation to the participants was consistent. The use of standard HTML also ensured that no restrictions were imposed by device or operating system used to run the web browser. The web survey was tested on personal computers, laptops, notebooks, and netbook computers, as well as tablets and smart phone devices, running the following operating systems iOS, OSX 10.6 and 10.7, Microsoft Windows XP, 7, Server 2003, and 2008, Linux Ubuntu 11.10 and 12.04, plus Android Honeycomb and Ice Cream Sandwich. Participants took part in the survey in any Internet accessible location internationally or nationally such as domestic residences, educational institutions, workplaces, and public areas. The survey was anonymous with no web cookies deployed to the web browsers to track or allow recommencement of an incomplete survey, or prevent retaking the survey multiple times. To ensure complete anonymity, no demographic details were requested or collected from participants. The only additional data detail collected with the responses to the visualisation questions was the time and date that the participant completed the survey to allow data records to be identified if a participant wished to withdraw before the commencement of data analysis.

Participants

Participation in the Internet web survey was voluntary. The email address, tvs.url@waikato.ac.nz, was established and configured to automatically reply to any email received with the URL of the survey. Volunteers were sought by distributing flyers and posters with the URL of the survey, the email address, and a QR Code containing the email address, across the University of Waikato campus. The survey URL and email address were advertised in the social media sites, Linked-In, Google Plus, Facebook, and the gaming web site Steam. A total of 128 participants volunteered to take part in the survey; 107 completed the survey, and 21 failed to complete therefore their incomplete data records were rejected from the data set used for analysis.

Materials

Four temporal information visualisation techniques were evaluated, each requiring five temporal information visualisation images. The graphic packages Adobe Photoshop and the GNU Image Manipulation Program (GIMP) were evaluated for their ability to place a two dimensional (2D) image into a 3D image with correct perspective. Both Adobe Photoshop and GIMP provide perspective correction tools that can manipulate images to remove lens induced distortions such as barrel and pincushion effects where the field of view does not match that of the lens at the focal length set for the image in one or more vertices. The perspective correction tool of these two packages is also used to extract the planar, 2D, view of a sub image from an image, for example a work of art hanging on the wall of a gallery viewed in perspective looking down the length of the gallery. The perspective correction tool can be used to add perspective to a planar image. The image Figure 6 depicts a time line of the works of Dickens in both textual and image form along with images of some of the houses in which Dickens resided.

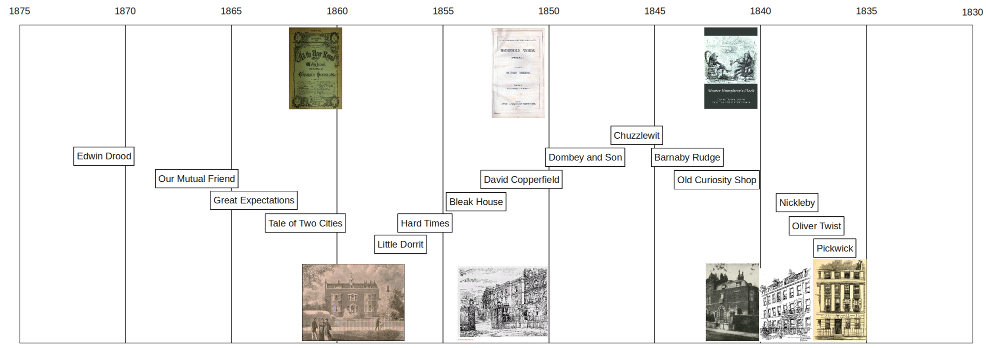

Figure 6. Dickens time line.

Using the perspective correction tool in GIMP the image has been manipulated to produce the perspective transformed image Figure 7.

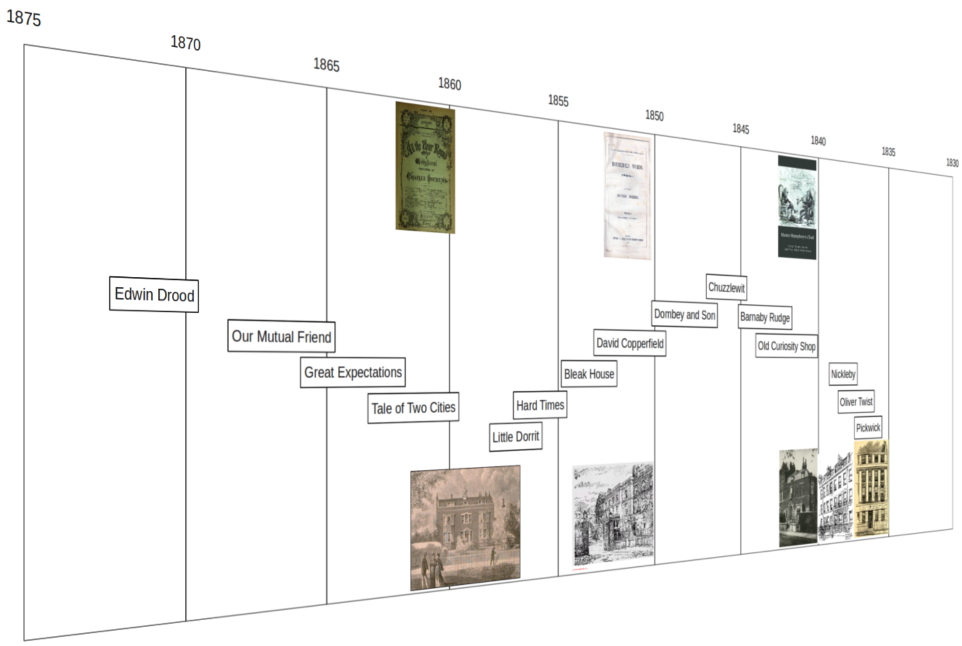

Figure 7. Dickens 3D time line.

In both packages, Adobe Photoshop and GIMP, the perspective correction tool requires manual manipulation of the grid transform therefore the angle of incidence of view and the proportionality of depth of view are not a precise perspective but dependent on the eye and skill of the practitioner utilising the tool. Neither Adobe Photoshop nor GIMP can generate perspective transforms based on specifying the field of view, depth, or angle of view incidence. The 3D computer graphic packages, Autodesk Maya (Maya) and Blender, support the manipulation of polygon structures in a 3D space with true perspective rendering via specification of a three coordinate location, a three axial orientation, and field of view. Image transforms can be achieved by generating a simple two dimensional polygon mesh object and applying the image to the object with texture mapping. Both Maya and Blender were rejected due to the complexity of their respective user interfaces requiring a complex and knowledgeable skill set. Programming with a 3D graphic library provided a solution that was flexible, with the ability to automatically scale and transform temporal object images quickly, thus allowing a rapid development and test cycle.

The open source graphics library Clutter is a core component of the GNOME Project desktop environment. Originally developed by OpenedHand LTD, now part of the Intel Corporation, Clutter is licensed under the GNU Lesser General Public License (LGPL) version 2.1 which allows developers and companies to use and integrate LGPL software into their own software without being required to release their own source code. Clutter is used to produce, fast, portable, and dynamic, graphical user interfaces. It works by manipulating 2D images, called 'actors', inside a 3D space, or stage, utilising true perspective. Clutter simplifies the creation of 3D interfaces. It is implemented using the C programming language with API bindings for C++, Perl, Ruby, Python, Vala, C#, JavaScript, and Haskell across Linux, Apple Mac OSX, and Microsoft Windows operating systems (GNOME Project, 2012). Feasibility testing to produce temporal information visualisations was conducted using Clutter 1.0, consisting of libclutter-1.0-0 and dependencies of the Ubuntu Oneiric 11.10 Canonical supported Open Source software main repository and the C++ compiler gcc 4.6 4.6.1-9ubuntu3 and dependencies.

Initial testing of the Clutter library for production of 3D temporal information visualisations centred on its ability to produce images incorporating temporal object images in a true perspective relationship. Temporal object images were placed at various points of depth along the *z* axis of linear perspective lines with interposition and no occultation, to establish comparative perspective image sizes. Temporal object images were also rotated about the vertical axis, both to the left and the right and to various angles of incidence away from the planar view, to evaluate perspective transforms.

Once the Clutter library was proven to produce accurate spatial temporal information visualisation images with temporal object images in true perspective, the next goal was to establish an image of a spatial 3D environment consisting of a plane with a horizon using either linear or gradient perspective cues or a combination of both. The plane was constructed as a Clutter group anchored at the front bottom edge of the stage employing dynamic sizing derived from the size of the stage to establish a true perspective horizon. Texture maps consisting of images with strong geometric patterns such as parquet floor tiles, floor boards, tiles of clay, ceramic, and stone, as well as geometric patterns including circles, checks, and a combined octagonal and square interlocked pattern, were applied, scaled to the size of the plane and unscaled tiled over the plane to evaluate their ability to impart depth via gradient and/or linear perspective cues. All of the image texture maps provided strong foreground perspective cues but suffered from poor blending at deeper background perspectives near the horizon especially when depth perception was heavily reliant on texture maps utilising texture gradient as a perspective cue with weak linear perspective cues. To remedy the loss of perspective cues near the horizon, the texture maps were replaced with a grid of lines providing a strong linear perspective. They were constructed from Clutter rectangle actors configured as lines running parallel to the horizon and along the lines of linear perspective. The width and number of Clutter rectangle line actors and the ratio of the linear intersections were calculated via a formula based on the stage size to provide optimal linear perspective cues across the full perspective depth. To emphasise the horizon, a sky was added to the stage constructed from a single Clutter rectangle actor, appropriately coloured "deep sky blue", and anchored to the front top of the stage. The Clutter fog function allowed the application of an atmospheric perspective cue.

On completing the spatial environment 3D scene, image testing continued to the next step of incorporating temporal object images into the scene. The arrangement of the two temporal object images was along the central linear line of perspective to remove any temporal cue induced by left/right or right/left ordering of the images. To ensure that the images were not in any form of interposition they were scaled to minimise the dominance of the foreground image with the background image placed at a deep position on the *z* axis ensuring clear visual separation of the images. The scaling and positioning of the temporal object images resulted in both images constituting a small percentage of the scene image for the 3D temporal information visualisation. To increase the area of the visualisation devoted to the temporal object images the stage on which the scene was constructed was rotated around the front bottom edge by rotating the Clutter group comprising the plane and the sky Clutter rectangle actor. This raised the horizon in the image so in effect increased the height of the observer or camera point. Raising the horizon lengthens the depth of the perspective providing more visual length. This allowed the background temporal image to be placed closer to the observer thus increasing the size of the background temporal object image in relationship to the foreground temporal object image as well as allowing an increase in scale of both temporal object images.

The remaining two spatial temporal information visualisation techniques incorporated a single linear temporal line for temporal progression so that the temporal object images appeared in the visualisation like images hanging on a wall. One set of five visualisations depicted the temporal object images on a wall to the left of the observer and the other five visualisations a wall on the right. The stage was uniformly black with no perspective cues other than the perspective transforms of the temporal object images. The temporal object images were placed in a Clutter group which was then rotated either to the left or right so the planar view was at an angle of incidence of fifty degrees rotation from the observer. This angle of incidence placed the vanishing point, or perspective focal, just outside the field of view of the information visualisation. Scaling of the temporal object images was dependent on the size of the Clutter stage forming the visualisation image with the scaling factor set to maximise the temporal object images within the information visualisation image, while minimising the dominance of the foreground temporal object image.

The five common temporal visualisation technique images of a single horizontal axis time line were constructed with the stage uniformly black, and a single Clutter rectangle actor configured as a horizontal line was placed beneath the two temporal object images which were arranged horizontally adjacent to each other. The horizontal line, representing the time line, was made temporally neutral by not terminating either end with arrow heads. The scaling calculation of the temporal object images was dependent on the size of the Clutter stage forming the visualisation image with the scaling factor set to maximise the temporal object images within the information visualisation image while ensuring clear separation between the temporal object images.

Each of the four temporal information visualisation technique image C++ instruction sets utilising the Clutter library was compiled in a separate dedicated program listed in Appendix C. A Bash script was used to generate all four temporal information visualisation technique images for a temporal object image pair, also listed in Appendix C. The four programs generating the temporal information visualisation technique images also produced size and coordinate details of the temporal object images within a visualisation to assist with post image generation editing to produce mat masks, highlight fills, and sub image objects.

Temporal object image pair selection criteria were formulated to provide real world temporal object images while minimising the effect of participant's prior knowledge. This was done by compiling a diverse list of temporal subjects as follows: Agatha Christie crime novels, Apollo moon missions, antique German ceramic dolls, Cray super computers, de Vinci art works, electro hydro dams on the Waikato river, English regents, equine bloodstock, Fabergè eggs, fashion, flowers, Greek vases, John Harrison marine timekeepers, Lalique perfume bottles, landscape shadows, lunar phases, maritime history, movie posters, postage stamps, Rodin bronzes, Singapore currency, video games, and wearable arts. The uniformity of the temporal object image pairs was included in the selection criteria; this included ensuring that the images had neutral backgrounds or at least similar backgrounds with no temporal cues. To reduce the ability to research the relationship between the temporal object images the selection criteria sought temporal objects with minimal temporal duration between the objects. An Internet search engine test was conducted for each subject and question with the size and content of the result pool evaluated to establish the likelihood that an answer could be found. A large result pool indicated that the subject and question were generic thus making a successful search unlikely. A small result pool indicated that the subject and question were obscure. In either case, the first three pages of the search results were checked for the answer with the question rejected if found.

In all of the temporal information visualisations depicted with spatial cues, the youngest or newest temporal object image was placed in the foreground while the oldest temporal object image was placed in the background. The arrangement of the temporal object images equates to the spatial example of two stars, one four light years away and the other eight light years away. The star eight light years away is placed in the background as its light has taken longer to reach the observer due to its greater distance from the observer whereas the star four light years away is in the foreground as it is closer to the observer. The temporal object images in the temporal information visualisations using the technique of a single horizontal axis time line were arranged with the oldest temporal object on the left, and the newest or youngest temporal object placed to the right of the oldest temporal object image as is the common practice for societies that use a left to right writing technique.

Measurement Instrument

The instrument selected for evaluating the temporal information visualisation techniques was a survey which could be conducted as a paper based survey or digital computer based survey. A digital computer based survey was chosen as it provided accurate data collection removing the need to interpret the intention of a participant due to multiple selection, cancellation of selection, changed selection, reselection, or not marking the selection clearly. The options for a digital computer based survey were to develop a survey package, utilise an existing survey application, or a web based survey site. Web based survey packages were evaluated first. To minimise spatial cues influencing the temporal decision of the participant, the web survey site was evaluated on its ability to directly select portions of an image as a response to a question. Web survey sites rejected for poor graphical selection options were Checkbox Survey (www.checkbox.com), KiwikSurveys (kiwiksurveys.com), Snap Surveys (www.snapsurveys.com), SurveyMonkey (www.surveymonkey.com), and Web Survey Creator (www.websurveycreator.com). Two Internet web survey sites supported graphical sub-image selection, Qualtrics (www.qualtrics.com) and Survey Writer (www.surveywriter.com). Qualtrics was rejected as it allowed multiple sub-image selection and no selection as a response to a question. This deficiency could not be mitigated by defining rules for participant question response. Survey Writer allowed the specification of the number of sub-image selections within an image and included a sophisticated dynamic rule parser which could evaluate a participant's response to a question, issue a customised error message when required, as well as redirect the participant to repeat a question or move to another question. The charging for Survey Writer is per participant completion of the survey with a minimum charge based on 250 participants. There is no time limit or charge for construction or hosting the survey. A test question was constructed with Survey Writer that confirmed that it fulfilled the requirements of the survey. The Survey Writer security and confidentiality policy was checked to ensure it would meet the requirements for ethical consent under the Ethical Conduct in Human Research and Related Activities Regulations. The Survey Writer security and confidentiality policy includes a clause where Survey Writer will agree to abide by the security and confidentiality policy of the client. Agreement was sought and obtained in writing where Survey Writer would abide by the University of Waikato Ethical Conduct in Human Research and Related Activities Regulations.

The Survey Writer web survey construction application required the use of Microsoft Internet Explorer. Converting the temporal information visualisation images to act as a graphical answers in Survey Writer required the temporal object sub-images extracted to be independent graphic objects. The temporal object image extraction from the visualisation image was performed with GIMP. It was then used to create a mat mask of the temporal information visualisation with the temporal object images replaced with a green highlighted area matching the area occupied by the temporal object images. Extraction of the temporal object images and the editing of the visualisation images were assisted by the location and size details the image generation program displayed during the construction of the temporal information visualisation image. The image files were then uploaded into the Survey Writer project created to construct and run the survey.

The survey questions were constructed using the single choice radio button question type. After selecting the question type the question text was entered. Next, the background mat mask image was incorporated into the question as a general graphic image. The temporal object sub-images were added as question answer options and assigned response return values. The survey standardised on the response value of 1 for the oldest temporal object, and 2 for the newest, youngest temporal object image. The question type was then converted to a "Click Pick" which activated the question build feature that allows the incorporation of graphic images as choice selection targets. The question options selected set the answer required flag which prevented the participant from progressing to the next question unless an answer was supplied for the current question. The "Click Pick" question type automatically sets the custom script option which is required to hold the scripting to enable the graphic images as choice selection targets. Executing the "Click Pick" build feature enabled the setting of the image control details for each temporal object image. This dictated the location and size of the temporal object image therefore defining the click selection area for the temporal object image, and the graphic transform to be applied to the selected image. For the survey, the graphic transform decreased the opacity of the image by 50% allowing the green highlighted area behind the temporal image to be partially visible thus highlighting the selected image. The specification of the location placement and size details of the temporal object images were copied from the location and size details the image generation program displayed during the construction of the temporal information visualisation image.

In testing the survey questions using the web browser Microsoft Internet Explorer a vertical and horizontal offset was observable between the temporal object images and their green highlighted areas in the information visualisation mat image. The image offset was due to a different point of origin being used for the information visualisation mat image and the temporal object image graphic selection target placement coordinates. Testing with other web browsers such as Mozilla Firefox and Google Chrome also showed image offsets but with different degrees of offset. To remove the difference in origin points the information visualisation mat image graphic was converted to a temporal object image selection target graphic and added as a question answer with a response value of zero. The effect of incorporating the information visualisation mat image graphic as a temporal object image selection target graphic allowed the participant to select the information visualisation and therefore deselect the temporal object image selected. To prevent the selection of the information visualisation mat as the answer, thus returning zero, the question options were modified by setting a validation filter which displayed an error message requesting the participant select a temporal object image if the current selected return value was zero.

The survey was constructed with five questions for each of the four temporal information visualisation techniques so a participant's temporal orientation for a technique had to fall into one or the other orientations depicted in the technique such as left for oldest, right for youngest in a horizontal time line or vice versa. The degree of the participant's orientation could be determined by the number of questions answered with the same orientation, with three out of five, a 60% degree of orientation; four out of five an orientation of 80%, and five out of five a 100% confirmation of temporal progression orientation. The questions for each temporal information visualisation technique were grouped with the first set of five depicting the common horizontal axis time line technique and numbered 11 to 15 to identify them in the result output. The second set of five questions numbered 21 to 25 used the spatial 3D temporal information visualisation technique. The spatial temporal information visualisation technique that visualised the temporal objects as images hanging on a wall to the right of the observer were number 31 to 35. The last set of questions numbered 41 to 45 were the 3D temporal information visualisation technique where temporal objects were visualised as images hanging on a wall to the left of the observer. To minimise the possibility of participant training derived from the presentation order of the visualisation techniques the question order was partially randomised. This had the added benefit of reducing familiarity of any participant retaking the survey. The Survey Writer question randomisation facility allows the specification of groups of randomised questions. Four randomisation groups were established with group 1 containing questions 11, 12, and 13; group 2 containing questions 14, 15, 21, and 22, and group 3 questions 24, 25, 31, and 32. The remaining questions 33 to 35 and 41 to 45 were placed in group 4. Question 23 was not in a randomisation group and was therefore always presented to the participants as the eighth question. This allowed it to act as an anchor point in the survey result output which could be produced in question order or order of presentation to the participant.

The question text for each temporal information visualisation was balanced between the number of oldest and youngest temporal objects being the correct answer to minimise participant training. The question texts were also grammatically reviewed to reduce misinterpretation or misunderstanding by the participant.

The web survey was preceded by a web page providing instructions, details of participants' rights and how to exercise those rights, along with details on how to contact the researcher and the researcher's supervisor. Google groups were used to establish alias email addresses for the researcher and supervisor to prevent harvesting of personal contact details. The last survey question was followed by a web page that thanked the participant, reiterated participants' rights, how to exercise those rights, and contact details of the researcher and the researcher's supervisor. The last web page closed with a reference list of the images used in the survey.

The web survey is presented, in question order, in Appendix A.

Human participation in the study via the web survey required the approval of the Ethics Committee, Faculty of Computing and Mathematical Sciences, under the Ethical Conduct in Human Research and Related Activities Regulations. The application documentation submitted for ethical consent is presented in Appendix B along with the letter conferring consent to the Internet survey.

Data Collection

On the granting of ethics approval, the web survey was made public by publishing the URL of the survey project. Recording of participant responses commenced with the publication of the URL. The web survey was open to participants for a period of six weeks. The Survey Writer project closure procedure required the creation of a closure message which thanked the web user for their interest and informed them that the survey was closed for participation. During the six week period that the survey was open, one participant requested clarification of a question regarding the ambiguity of a question. The researcher identified this as a case of perceived temporal fictive motion on the part of the participant. The researcher replied to the participant explaining temporal fictive motion and recommending a paper regarding temporal fictive motion that the participant could pursue if they wished to research the topic further. One request was received for a summary of findings. No other correspondence was received while the survey was open to participants and no correspondence has been received since the closure of the survey.

Data Analysis

Analysis of the responses from the 107 survey participants was performed with a Perl script executed with Perl 5.12.4 running on Ubuntu Oneiric 11.10. The Perl script utilised the Perl modules, Chart::Clicker, Math::NumberCruncher, Statistics::Descriptive, Statistics::Distribution, and Statistics::Frequency. The statistical output of the Perl script, including basic bar graphs, can be viewed in Appendix D. The Perl script is in Appendix E. The script also produced graphic image files of the bar graphs for inclusion in this thesis. Descriptive statistics were used to analyse the temporal orientation of the participants for each question in each temporal information visualisation technique. This analysis was then combined by frequency grouping to provide an overall temporal orientation trend for each technique. The temporal orientation frequency grouping for each temporal information visualisation technique was tested using a chi-square test to evaluate how closely the frequency distribution compared to a random frequency distribution. A failure to match a random distribution indicated an underlying temporal orientation in the participants thus supporting the hypothesis that spatial, 3D, visualisation of temporal relationships between objects is intuitive as it utilises the viewers pre-existing cognitive construct of space time. Participants found to have definitive temporal orientation for the spatial 3D temporal information visualisation technique were extracted as a sub sample and an analysis performed to evaluate the consistency of the temporal orientation across the 3D temporal information visualisation techniques that presented temporal objects in a manner similar to images hanging on a wall.

Chapter 4

Analysis of Research Survey Responses

This study followed a quantitative model utilising a web survey seeking participants responses to temporal progression visualisations constructed using four different temporal progression information visualisation techniques for comparison and evaluation. The four techniques consisted of a single horizontal axis time line commonly used for visualising temporal object relationships and three techniques using 3D to visualise temporal object relationships in a spatial context.

The responses by each participant to the four information visualisation techniques were compiled to establish a trend of temporal perception/orientation for each information visualisation technique. These trends were combined across all participants for each visualisation technique and statistically analysed to establish an overall trend of temporal perception/orientation. Comparisons were then conducted between the statistical results of each visualisation technique and combinations of technique. Where strong temporal perceptions were detected for a visualisation technique the participants were extracted as a sub sample and their trend results analysed across the other temporal visualisation techniques.

Statistical analysis of the responses of the 107 participants was performed with a Perl script executed with Perl 5.12.4 running on Ubuntu Oneiric 11.10. The statistical output of the Perl script, including basic bar graphs, can be viewed in Appendix D. The Perl script is in Appendix E.

Survey Response

The web survey responses of the 107 participants are listed as a percentage match of expected outcome for each question in Table 1. The questions are grouped by information visualisation technique in a matrix with descriptive statistical results, mean, median, variance, and standard deviation, listed for each temporal progression information technique.

Table 1 Participant temporal orientation matching expected outcome.

Participant temporal orientation matching expected outcome as a percentage grouped by information visualisation technique with statistical descriptive analysis.

	Temporal progression information visualisation technique.			
Question	Time line	Spatial 3D	Spatial right wall	Spatial left wall
1	42%	80%	49%	57%
2	32%	62%	76%	62%
3	52%	59%	58%	49%
4	61%	63%	61%	61%
5	59%	59%	47%	80%
Mean	49	64	58	62
Median	52	62	58	61
Variance	148	82	134	136
Standard deviation	12	9	12	12

Of the four temporal progression information visualisation techniques tested in the survey, participant responses most closely matched the expected outcomes for the spatial, 3D, (Spatial 3D) temporal progression information technique with a mean of 64% or 342 responses out of out of 535 matching expected outcomes. Along with having the highest mean success rate the technique also had the lowest variation in responses with a variance of 82 and a standard deviation of 9. The responses for spatial information visualisation technique that employed a single linear line for temporal progression with the temporal object images appearing in the visualisation in a manner similar to images hanging on a left wall (Spatial Left Wall) matched expected outcomes with a mean of 62%, variance of 136, and standard deviation of 12. The responses for spatial information visualisation technique that employed a single linear line for temporal progression so the temporal object images appeared in the visualisation in a manner similar to images hanging on a wall to the right of the observer (Spatial Right Wall) matched expected outcomes with a mean of 58%, variance of 134, and standard deviation of 12. The time line temporal progression information visualisations employing a horizontal axis line constructed with the past on the left of the visualisation (Time Line) responses were the lowest with a success rate of matches to an expected outcomes mean of 49% or 262 responses out of 535. The variance of the responses to the Time Line group of questions was the greatest at 148, giving a standard deviation of 12. The mean 49% success rate for the Time Line temporal progression information visualisations is unexpected as this type of temporal progression visualisation is common and therefore familiar to the survey participants in comparison to the spatial temporal progression visualisations. The Spatial Right Wall mean of 58%, making the technique the lowest of the three spatial temporal progression information visualisation techniques, is also unexpected.

Figure 8 depicts the participant success rate for all questions across all temporal progression information visualisation techniques. Two participants achieved a success rate of 19 responses out of 20 matching expected outcomes. The lowest success rate is a participant with six responses matching expected outcomes. The low value of 30% and upper value 95% bracket a success rate range of 65 for responses matching expected outcomes. The mean success rate across all 20 survey questions is 58%, with a median of 55%. The variance is 235 with a standard deviation of 15 which is larger than the standard deviation of any of the temporal progression information visualisation technique question sets indicating that there is a difference in how the respondents understood and responded to the

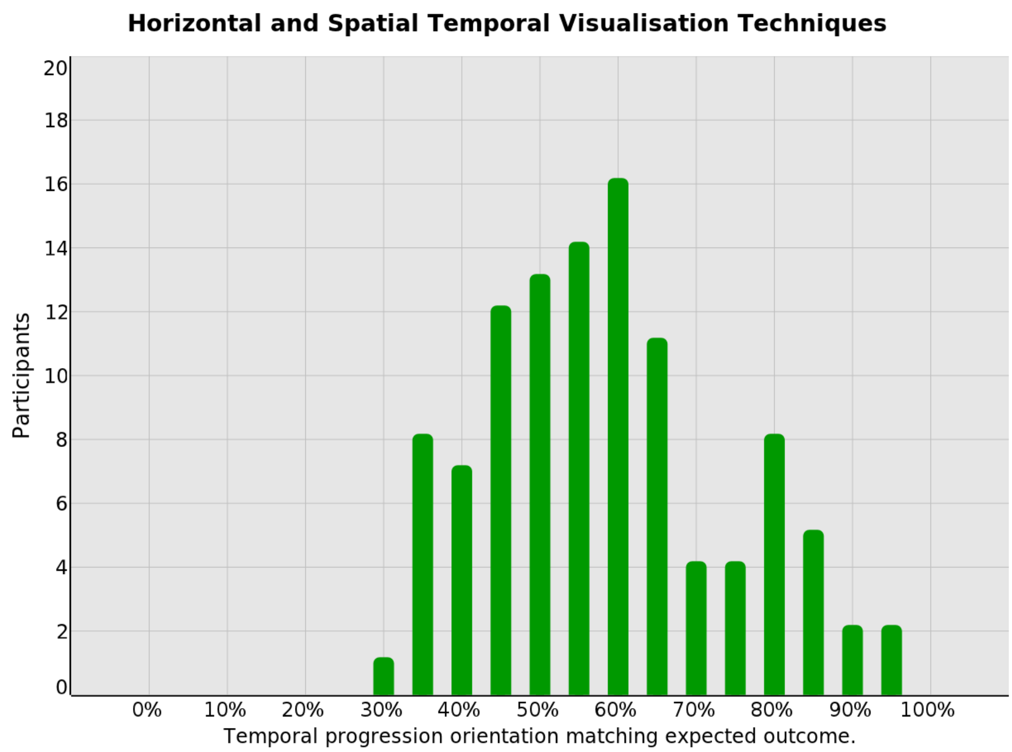

Figure 8. Temporal progression orientation matching expected outcomes.

different temporal progression information visualisation techniques. There are no outliers identified in Figure 8. Therefore no trimming of the dataset is required or caveats noted for analysis of all 107 participants responses to all temporal progression information visualisation techniques.

The approach taken for the analysis of each temporal progression information visualisation technique was to establish the temporal progression orientation trend of each participant by calculating a percentage of responses that matched expected outcome for each visualisation technique. For example, a participant with five out of five responses matching the expected outcome is deemed to have an orientation of 100% matching the expected temporal progression orientation, four out of five, 80%; three out of five, 60%; down to zero out of five, 0%, or a temporal progression orientation the complete reverse of the expected. The use of five questions per temporal progression information visualisation ensures that a respondent cannot have a neutral temporal progression orientation but must exhibit an orientation either in favour or against the expected orientation. Where analysis of combinations of temporal progression information visualisation techniques is performed the combined larger participant response sets of 10 or 15 responses have been normalised to the 20% interval range, of a five response set.

Time Line

The time line temporal progression orientation for the 107 participants is indeterminate as shown in Figure 9. The mean orientation trend is 49, with a

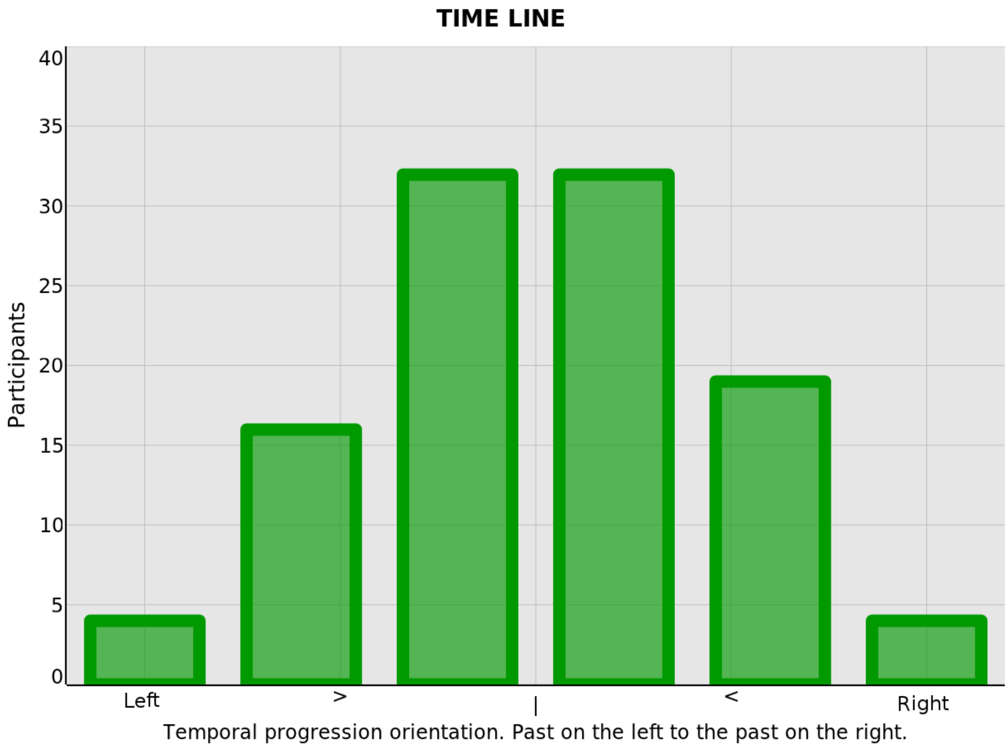

Figure 9. Participant horizontal left/right temporal progression orientation.

median of 40, variance of 546, and standard deviation of 23. The uniformity of the distribution and the centralisation of the mean raises the question of whether the responses to the time line temporal information visualisations are random.

A binomial distribution approximates a random temporal progression orientation equivalent to participants tossing a coin to select the temporal object image response. The temporal progression trends of the 107 participants are plotted against the random binomial distribution in Figure 10. Visually the two distributions are similar, but not identical, therefore a statistical test is required to evaluate how closely the participant responses for the time line temporal progression information visualisations approximate random responses.

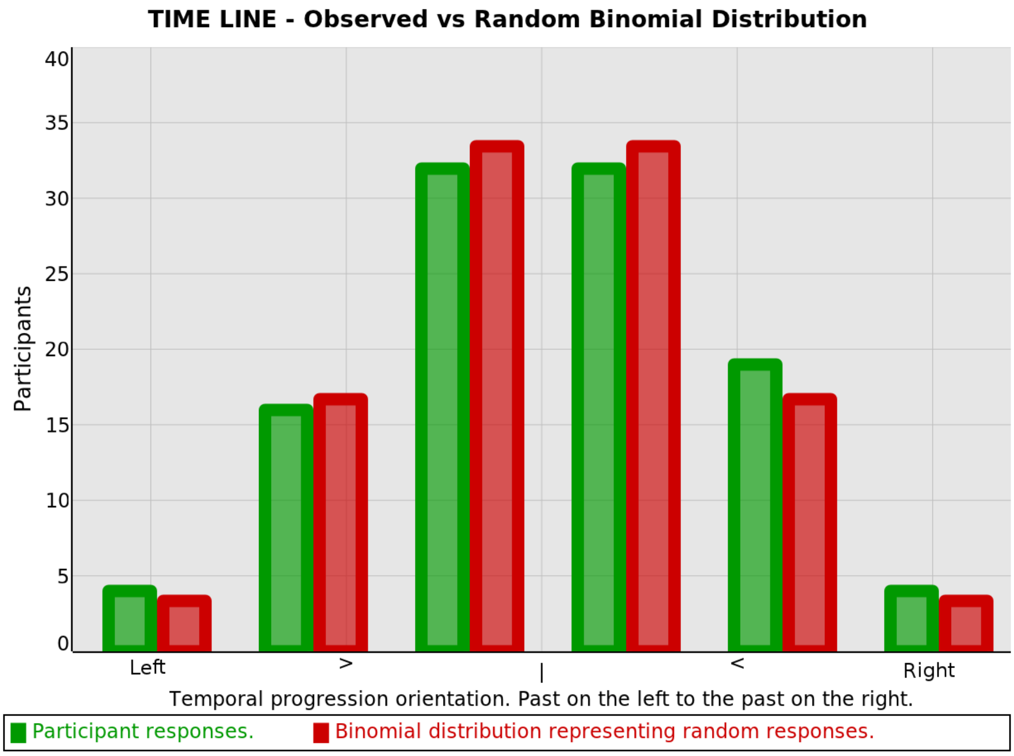

Figure 10. Time line observed and random binomial distribution comparison.

The chi-square (X^2) provides a test based on the difference between observed and expected frequency outcomes. The X^2 value is the sum of the observed values less the expected values squared divided by the expected value.

$$X^2 \equiv \sum \frac{(O - E)^2}{E}$$

The X^2 value also requires a degrees of freedom (*d.f.*) value based on the number of trials (*k*) and is normally calculated as one less the number of trials. The temporal progression orientation trend for each participant can fall into one of the six 20% intervals from 0% to 100%. Therefore the trend outcome is the equivalent to a trial. The X^2 value with the *d.f.* value is used to reference the chi-square distribution function to produce a probability (*p-value*) that the distributions being tested are identical.

The null hypothesis (H_0) for the chi-square test is that there is no difference between the two distributions therefore the participant responses for the time line temporal progression information visualisations can be considered to be random.

The calculated X^2 is 0.723 with *d.f.* of 5 gives a *p-value* of 0.982, therefore H_0 is accepted and the participant responses to the time line temporal progression information visualisations can be considered random which invalidates them for the purpose of this study.

Spatial 3D

The temporal orientation trend of the participants derived from the responses for the spatial, 3D, temporal progression information visualisations depicted in Figure 11 indicates that 73 participants out of 107 or 68%, associate the spatial depth of a temporal image with temporal age where the greater the depth of the temporal object image within the information visualisation image equates to a greater age of the temporal object. The mean temporal progression orientation trend matching expected outcome is 64, with a median of 60, variance of 712, and standard deviation of 27. The chi-square test was applied to the spatial, 3D, temporal progression orientation trend distribution comparing it to the binomial distribution equivalent to a random orientation distribution with the null

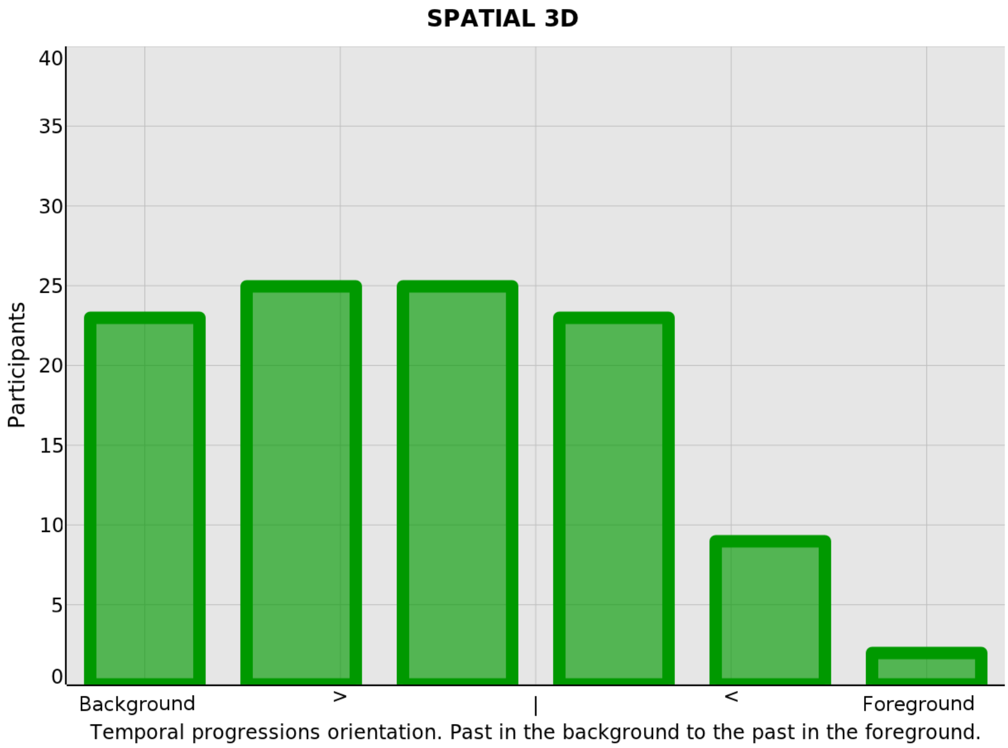

Figure 11. Participant spatial temporal progression orientation.

hypothesis (H_0) that there is no difference between the two distributions therefore the participant responses can be considered to be random. The determinant *p-value* establishes the strength or weakness of the spatial temporal association being exhibited by the participants. The calculated X^2 is 129.142 with *d.f.* of 5 gives a *p-value* of 0.000, therefore H_0 is rejected. The low *p-value*, in this case zero to three decimal places, indicates the temporal progression orientation trend of depth for time is very significant.

Spatial Right Wall

The temporal orientation trend for the spatial right wall temporal progression visualisations that employed a single linear temporal progression line where the temporal object images appeared in a manner similar to images hanging on a wall to the right of the observer is depicted in Figure 12. Of the 107 participants 67 or 62%, associate spatial depth of a temporal object image with temporal age where the greater the depth of the temporal object image within the information visualisation image the greater the age of the temporal object. The mean temporal progression orientation trend is 58, with a median of 60, variance of 679, and standard deviation of 26. The chi-square test was applied to the spatial right wall temporal progression orientation trend distribution comparing it to the binomial distribution equivalent to a random orientation distribution with the null

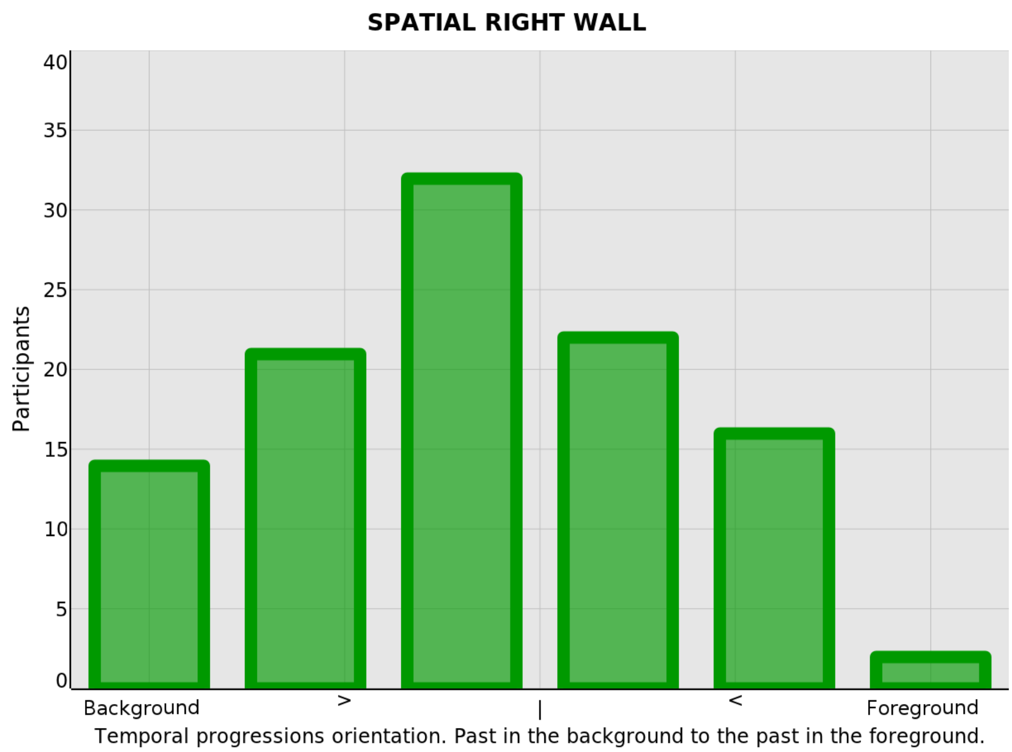

Figure 12. Participant spatial right wall temporal progression orientation.

hypothesis (H_0) that there is no difference between the two distributions therefore the participant responses can be considered to be random. The calculated X^2 is 39.602 with a *d.f.* of 5 gives a *p-value* of 0.000, therefore H_0 is rejected. The low *p-value* indicates the temporal progression orientation trend of depth for time and therefore the spatial temporal association of the participants is very significant.

Spatial Left Wall

The temporal orientation trend for the spatial left wall temporal progression visualisations that employed a single linear line of temporal progression where the temporal object images appeared in a manner similar to images hanging on a wall to the left of the observer is depicted in Figure 13. Of the 107 participants 75 or

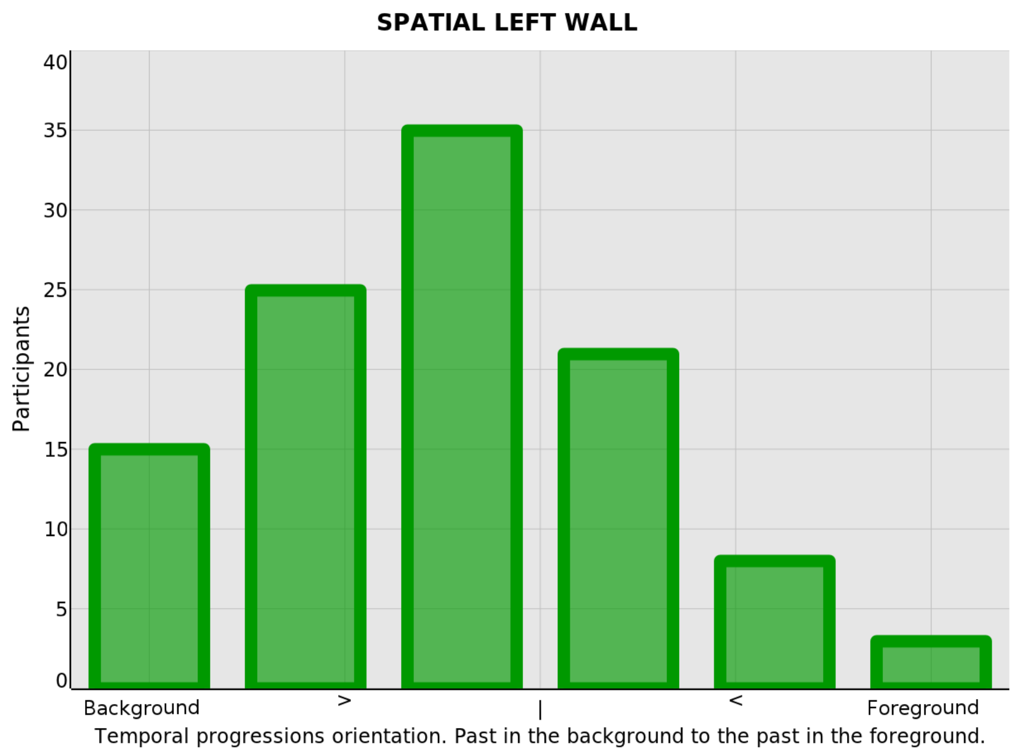

Figure 13. Participant spatial left wall temporal progression orientation.

70%, associate spatial depth of a temporal image with temporal age where the greater the depth of the temporal object image within the information visualisation image equates to the greater age of the temporal object. The Left Wall mean temporal progression orientation trend is 62, with a median of 60, variance of 620, and standard deviation of 25. The chi-square test was applied to the observed temporal progression orientation trend distribution comparing it to the random orientation distribution with the null hypothesis (H_0) that there is no difference between the two distributions therefore the participant responses can be considered random. The calculated X^2 is 54.017 with a *d.f.* of 5 gives a *p-value* of 0.000, therefore H_0 is rejected. The low *p-value* indicates the temporal progression orientation trend of depth for time for the spatial left wall temporal progression technique is very significant thus the participants have a strong spatial temporal association.

Combined Spatial Left and Right Wall

The combined spatial right and left wall temporal progression visualisations (Spatial Wall) that employed a single linear line with spatial depth, where the greater the depth of the temporal object in the visualisation the greater the age of the object, is depicted in Figure 14. The number of responses per participant in the combined spatial wall temporal progression information visualisations is ten, therefore the orientation trend has been normalised to match the intervals used in the analysis of each temporal progression information visualisation technique. Of the 107 participants 83 or 77%, associate spatial depth of a temporal image with

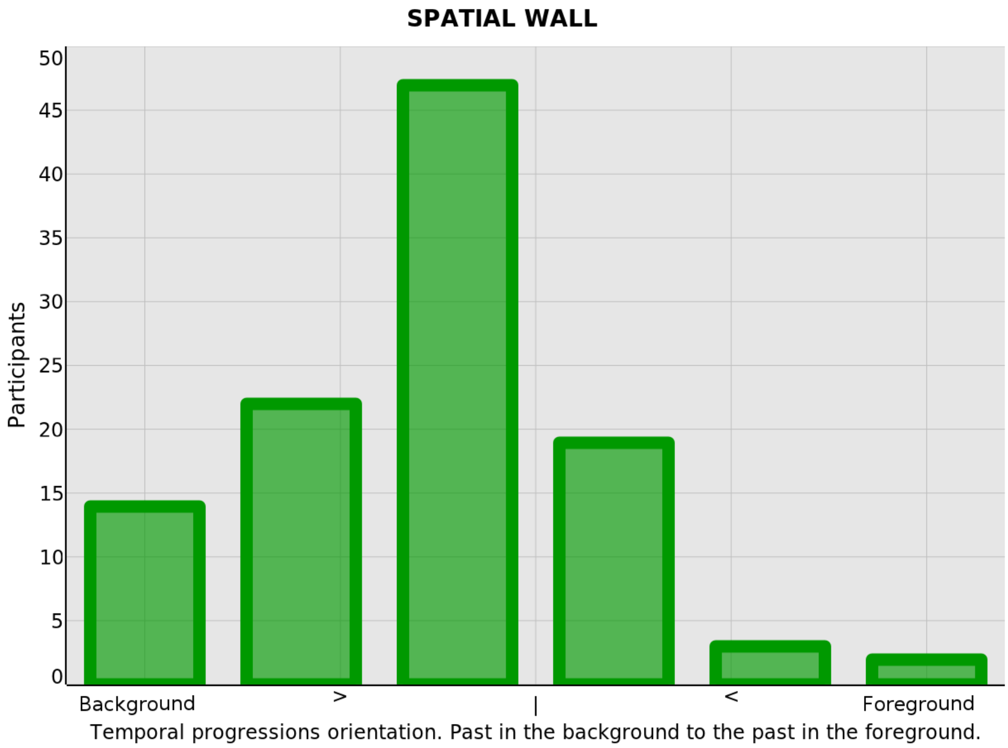

Figure 14. Participant combined spatial left and right wall temporal orientation.

temporal age where the greater the depth of the temporal object image within the information visualisation image the greater age of the temporal object. The Spatial Wall temporal progression orientation trend mean is 60, with a median of 60, variance of 377, and standard deviation of 19.

Combined Spatial

The combined spatial temporal progression visualisations (Spatial) where the greater the depth of the temporal object in the visualisation the greater the age of the object is depicted in Figure 15. The number of responses per participant in the combined spatial wall temporal progression information visualisations is fifteen,

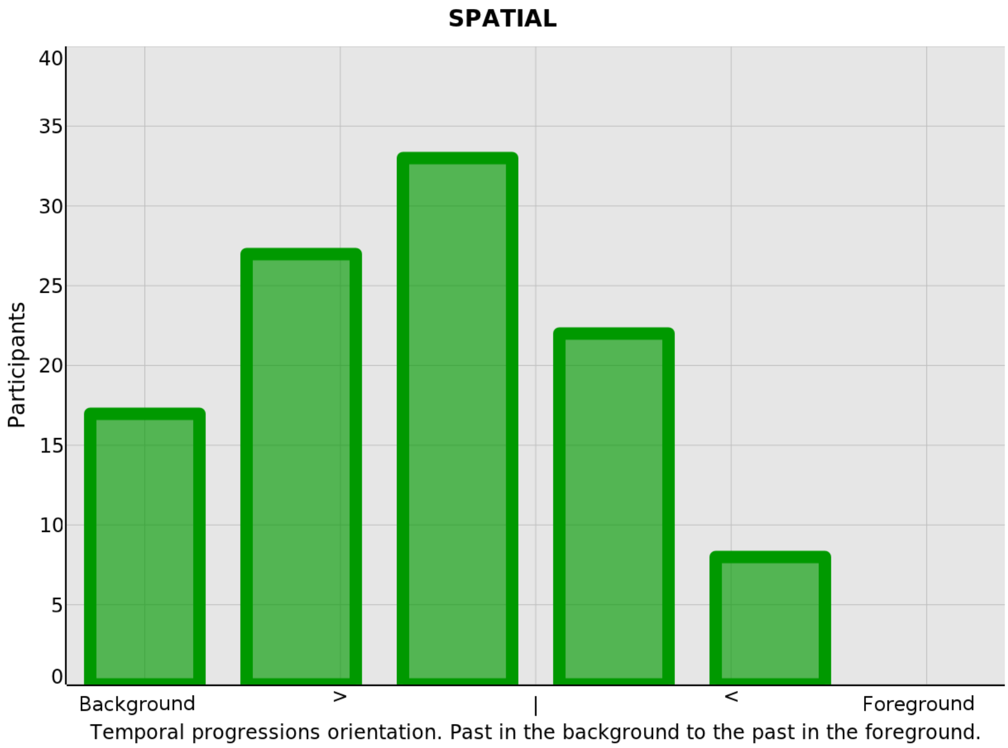

Figure 15. Participant combined spatial temporal progression orientation.

therefore the orientation trend has been normalised to match the intervals used in the analysis of each temporal progression information visualisation technique. Of the 107 participants 77 or 71%, associate spatial depth of a temporal image with temporal age. The Spatial Wall temporal progression orientation trend mean is 61, with a median of 60, variance of 340, and standard deviation of 18.

Spatial Temporal Association Conformance

To analyse spatial temporal association conformance participants with responses that matched all the expected outcomes for the spatial, 3D, temporal progression information visualisations were extracted as a subgroup. The participants in this subgroup exhibit a complete and coherent association between spatial depth and time. This spatially orientated subgroup contains 23 participants, 21% of the 107 survey participants. In Figure 11, the left most column labelled 'Background', depicts the scope of the spatially oriented subgroup.

The temporal orientation trend of the spatially orientated participants for the combined Spatial Left Wall and Spatial Right Wall temporal progression information visualisation is listed in Table 2.

Table 2 Spatial temporal conformance of spatially orientated participants.

Spatial temporal progression conformance across spatial temporal information visualisations that contain a single temporal line of progression of participants exhibiting a complete and coherent association between spatial depth and time.

Degree of orientation of depth for time	Participants	Participants accumulated	Participants accumulated percentage
100%	9	9	39%
80%	9	18	78%
60%	4	22	95%
40%	1		
20%	0		
0%	0		
Total	23		

The degree of orientation is the number of responses from each participant that match the expected outcomes as a percentage. The number of participants has been accumulated for each degree of orientation interval along with its equivalent percentage of participants in the spatially orientated participants group to allow analysis of the degrees of orientation with different floor values to the common ceiling.

The conformance of the participants with a spatial temporal association across the spatial temporal progression information visualisations containing a single temporal line of progression such that the temporal objects appear to the observer as images hanging on a wall is 39%. This figure implies that the arrangement of temporal images in a linear fashion degrades the spatial temporal association. However the spatial temporal association is still exhibited to some degree by 95% of the participants. Only one participant did not translate their spatial temporal association to linear temporal progression in a spatial setting.

The temporal orientation trend of the spatially orientated participants is categorised in Table 3 by the linear temporal progression Spatial Left Wall and Spatial Right Wall to evaluate the balance between these two spatial temporal information visualisation techniques. The Spatial Right Wall with 10 participants exhibiting a complete and coherent spatial temporal association is greater than the Spatial Left Wall with 8 participants. This difference could be attributed to the Spatial Right Wall linear temporal progression matching the left to right temporal progression that is reflected in societies and cultures with languages that have a left to right writing orientation. The participants in Table 3 with a lower spatial temporal association are equivalent in conformance between the two spatial temporal information visualisation techniques.

Table 3 Spatial temporal comparison of spatially orientated participants.

Spatial temporal progression conformance across spatial temporal information visualisations that contain a categorised single temporal line of progression of participants exhibiting a complete and coherent association between spatial depth and time.

Degree of orientation of depth for time	Spatial left wall			Spatial right wall		
	Participants	Participants accumulated		Participants	Participants accumulated	
100%	8	8	34%	10	10	43%
80%	7	15	65%	6	16	69%
60%	5	20	86%	5	21	91%
40%	2			1		
20%	1			1		
0%	0			1		
Total	23			23		

To evaluate the extent of spatial temporal association conformance beyond participants exhibiting a complete and coherent association between spatial depth and time, the spatially orientated participant subgroup scope was expanded to include participants with responses that matched a minimum of four out of five expected outcomes for the spatial, 3D, temporal progression information visualisations. The participants of the expanded spatially orientated subgroup exhibit a dominant association between spatial depth and time. The expanded subgroup contained 48 participants, 44% of the 107 survey participants. The participants of the expanded subgroup are depicted in the two left most columns in Figure 11. The temporal progression orientation trend of the dominantly spatially orientated participants for the combined Spatial Left Wall and Spatial Right Wall temporal progression information visualisation is listed in Table 4.

Table 4 Spatial temporal conformance of spatially dominant participants.

Spatial temporal progression conformance across spatial temporal information visualisations that contain a single temporal line of progression of participants exhibiting a dominant association between spatial depth and time.

Degree of orientation of depth for time	Participants	Participants accumulated	Participants accumulated percentage
100%	11	11	23%
80%	14	25	52%
60%	17	42	87%
40%	5		
20%	0		
0%	1		
Total	48		

The conformance of participants with a dominant temporal spatial association across the spatial temporal progression information visualisations containing a single temporal line of progression is 23%. This figure implies that the arrangement of temporal images in a linear fashion degrades the spatial temporal association. However the spatial temporal association is still exhibited to some degree by 87% of the participants. Only 6 participants or 12% did not translate their spatial temporal association to linear temporal progression in a spatial setting.

The temporal orientation trend of the spatially orientated participants is categorised in Table 5 by the linear temporal progression Spatial Left Wall and Spatial Right Wall to evaluate the balance between these two spatial temporal information visualisation techniques. The Spatial Left Wall with 25 participants exhibiting a dominant spatial temporal association is greater than for the Spatial Right Wall with 20 participants. However the overall spatial temporal association is equivalent for the Spatial Left Wall and Spatial Right Wall information visualisation techniques.

Table 5 Spatial temporal comparison of spatially dominant participants.

Spatial temporal progression conformance across spatial temporal information visualisations that contain a categorised single temporal line of progression of participants exhibiting a dominant association between spatial depth and time.

Degree of orientation of depth for time	Spatial left wall			Spatial right wall		
	Participants	Participants accumulated		Participants	Participants accumulated	
100%	11	11	23%	12	12	25%
80%	14	25	52%	8	20	41%
60%	11	36	75%	15	35	73%
40%	10			9		
20%	1			4		
0%	1			0		
Total	48			48		

Chapter 5

Conclusions

This thesis has examined the spatial temporal association of temporal perception and its application in information visualisations to visualise time. This study followed a quantitative model utilising a web survey to evaluate four temporal information visualisation techniques. The four techniques consisted of a single horizontal axis time line and three techniques using 3D to visualise temporal object relationships in a spatial context. Analysis of the survey responses shows that participants utilise spatial cues for temporal cognition.

Discussion

The time line information visualisation technique (Time Line) participant temporal orientation trend frequency distribution was evaluated with a chi-square (X^2) test against a binomial distribution representing temporal orientation trends generated by random selection. The null hypothesis (H_0) for test is that there is no difference between the two distributions therefore the participant responses for the time line temporal progression information visualisations can be considered to be random. The calculated X^2 was 0.723 with *d.f.* of 5 gives a *p-value* of 0.982, therefore H_0 is accepted and the participant responses to the Time Line visualisations are considered to be random which invalidated them for the purpose of the study.

The analysis of the temporal orientation trend of participant responses for the spatial temporal progression information visualisations utilising a spatial landscape constructed with a sky, horizon line, and plane, (Spatial 3D), showed 73 participants, 68%, associated space with time. This result supports the hypothesis that spatial, 3D, visualisation of temporal relationships between objects is intuitive as it utilises the viewers pre-existing cognitive construct of space time. The spatial temporal visualisations employing the Spatial Left Wall and Spatial Right Wall techniques also support the hypothesis with 75 or 70%, and 67 or 62%, of participants respectively associating space with time. Across all three spatial temporal progression information visualisation techniques 77 participants or 72%, exhibited a spatial temporal association. An argument can be made that since temporal progression information visualisations presented in a spatial context are intuitive it should be considered as a valid technique for displaying temporal relationships between objects. This approach is also supported through the view that the basis of visualisation is the externalising of internal concepts (Gärdenfors, 2003) where temporal concepts are viewed as spatial as is evident in child development (Piaget, 1969), language (Casasanto, et al., 2010), philosophy (Newman, 2009), and science (Barnett, 1949).

The Spatial 3D participant temporal progression orientation trend frequency distribution plotted in Figure 11 shows a strong spatial temporal association. The strength of this spatial temporal association is statistically supported by the high X^2 value of 129.142. The temporal progression orientation trend frequency distribution of the Spatial Right Wall and Spatial Left Wall plotted in figures 12 and 13 respectively are weaker resembling a skewed normal distribution. This weakness is also evident in the lower X^2 statistical results of 54.07 for the Spatial Left Wall, and 39.602 for the Spatial Right Wall. The spatial temporal progression information visualisation techniques used to construct the Spatial Left Wall and Spatial Right Wall visualisations depicted the temporal object images as if they were displayed on a wall. This visual arrangement of the temporal object images imparted a linear temporal progression which appears to have had a degrading effect on the spatial temporal association exhibited by participants.

Conformance of participant spatial temporal association across spatial temporal progression information visualisations was evident in 95% of participants who exhibited a complete and coherent spatial temporal association in Spatial 3D visualisations retaining their spatial temporal association across Spatial Left Wall and Spatial Right Wall visualisations (Table 2). When expanding the scope of the conformance evaluation to participants with a dominant spatial temporal association, (see Table 4), 87% of the participants retained their spatial temporal association across the Spatial Left Wall and Spatial Right Wall visualisations. This level of conformance shows that participants who exhibited spatial temporal association do so consistently across all spatial temporal progression visualisations.

The consistency of participant's spatial temporal association is equivalent between the Spatial Left Wall and Spatial Right Wall visualisations. This is an unexpected outcome as the Spatial Right Wall linear temporal progression is equivalent to a left to right temporal progression while the Spatial Left Wall linear temporal progression is diametrically opposed with a right to left temporal progression.

The left to right linear temporal progression matches the left to right temporal progression of time lines as constructed in societies and cultures with a left to right writing progression, such as English (Santiago et al., 2007; Weger & Pratt, 2008). Therefore the Spatial Right Wall visualisations include both the spatial temporal association and the left to right temporal progression and as such should have a higher success rate in responses to expected outcomes. This is because participants could utilise either or both methods to determine temporal relationships between the temporal objects. This raises the question of whether the orientation of the written progression of a language reflects the conceptualised orientation of temporal progression or restricts the expression of temporal progression orientation perception.

Limitations

The time line information visualisation technique was included in the study in an attempt to establish the influence, positive, negative, or neutral, of the linear temporal progression orientation of a participant on their spatial temporal progression orientation. The analysis of the Time Line temporal orientation trends revealed a centralised mean of 49% and a plotted uniform frequency distribution (Figure 9). This raises the question of whether participant's responses to the time line temporal information visualisations are random. Plotting a binomial distribution representing responses as if the participants had tossed a coin to make a selection of which temporal object image answered the survey question against the actual participant responses showed the distributions to be visually similar (see Figure 10). A chi-square test was performed with the null hypothesis (H_0) that there is no difference between the two distributions therefore the participant responses for the Time Line visualisations can be considered random. The calculated X^2 was 0.723 with a *d.f.* of 5 giving a *p-value* of 0.982. Therefore H_0 is accepted and the participant responses to the Time Line visualisations are considered to be random invalidating the responses for the intended purpose in the study. There are three possible explanations for the random nature of participant responses to the time line temporal progression visualisation.

- In Table 1 the two lowest success rate scores of participant responses matching expected outcomes were for the first two Time Line questions with 42% and 32% respectively. These low scores could be attributed to the participant's lack of familiarity with the web survey constructs, controls, and concepts. This lack could have been mitigated by providing initial questions, that could be discarded, allowing the participant to become familiar with the web survey environment.

- The questions and/or the time line temporal progression visualisations were poorly constructed leading to the question being misunderstood. Unintended time cues may have been incorporated in the temporal object images. In the case of the first question, the background of the temporal images is not completely uniform with a marked difference in the cast of the shadow. The temporal image incorrectly selected as the oldest had poor brightness balance making the image appear over exposed, or faded. The disparity between the temporal images should have been given greater weight in the selection process as this would have led to rejection of the images. Alternatively, an attempt could have been made to equalise the white balance between the two temporal object images.

- The researcher wrongly assumed participants would have a consistent temporal progression orientation for temporal objects arranged along a horizontal line. The assumption was arrived at from a review of the research work from psychologists Boroditsky, 2000; Weger and Pratt, 2008; Santiago, Lupiáñez, Pérez, & Funes, 2007; in the field of lingual representation of time. Based on the random nature of the participant responses to the time line temporal progression information visualisations it appears that participants may require additional temporal cues such as time and/or date stamps to establish the temporal progression orientation of a time line.

The use of real world images for the temporal objects in the web survey was recognised during construction as an issue. Temporal image selection was conducted with the objectives of minimising prior knowledge, ensuring uniform backgrounds, and reducing web search engine success though obscurity. Image selection should also have considered temporal cues such as puffed sleeves pertaining to a fashion era, artistic style evolving during an artist's life time, and the state of the temporal object, for example, vases where one is cracked and chipped.

Training of the participant by the order of the temporal information visualisation techniques was also considered in the construction phase of the web survey. This was mitigated by randomising the question order for groups of questions at the boundaries of the different visualisation technique question sets. This approach blurred the line between each visualisation technique question set but did not fully eliminate the notion that the participant was progressing through a series of different visualisation techniques. Randomising all the questions across all visualisation techniques would have been a better technique to eliminate participant training.

Recommendations for Future Research

Initial future research should consider minimising or eliminating the limitations identified in this study. The granularity of the temporal orientation trend could be increased by increasing the number of questions per temporal information visualisation technique. Particular attention should be paid to establishing why the Time Line visualisations resulted in participants responding in a manner equivalent to responses generated by random selection. It may be advisable to dedicate a study to the question of temporal progression orientation in information visualisations employing a horizontal linear temporal progression looking at the validity of orientation of written progression equating to orientation of temporal progression. This study could be extended to determine the need for temporal cues to establish temporal progression orientation.

Several avenues of research arise out of the results of the study supporting the hypothesis of this thesis. Firstly, does the intuitive nature of spatial visualisations for temporal relationships between objects improve cognitive performance in recognising temporal relationships? This could be evaluated by measuring the time taken to reach conclusions regarding temporal relationships in spatial temporal visualisations compared to linear temporal visualisations employing a horizontal temporal progression line. This line of research could be extended to evaluate saccades and fixations in spatial visualisations determining the balance between foreground and background image recognition and cognitive processing to reach temporal relationship conclusions. Secondly, the limits of context and detail in 3D visualisations need to be researched to establish rules for the construction of spatial, 3D visualisations. For example, how deep can an object be placed in perspective before detail is lost and its contribution to the visualisation becomes solely contextual, and what are the limits on the number and spacing of objects before context is lost? Research of spatial context and detail also needs to establish the positives and negatives of interposition. A further aspect of spatial context and detail research that needs to be considered is planar and non planar information object presentation. Field of view and its impact on perspective depth where increased field of view width increases foreground detail and context to the detriment of perspective depth and distortion of spatial cues needs investigation. Another avenue of research is evaluating what spatial cues are effective, and in what combination. Interactive spatial, 3D, visualisation could be another focus of research covering aspects such as methods of visualisation manipulation, retention of context, and methods of exploring detail. Finally, evolving 3D technology and hardware needs evaluation for generation and presentation of spatial information visualisations.

Conclusion

The hypothesis that spatial, 3D visualisation of temporal relationships between objects is intuitive as it utilises the viewers pre-existing cognitive construct of space time that is evident in language via the use of spatial metaphor for time, and is supported by the scientific view of space time espoused by both the special and general theories of relativity of Albert Einstein has been found to be supported by this quantitative study. For spatial temporal progression information visualisations utilising a spatial landscape constructed with a sky, horizon line, and plane, 68% of participants associated space with time and for all of the spatial temporal information visualisation techniques evaluated in the study 72% of participants exhibited spatial temporal association. Therefore it can be confidently stated that a minimum of two out of three participants exhibit a spatial temporal association. Extracting the participants who exhibited a dominant spatial temporal association for the spatial temporal progression information visualisations utilising a spatial landscape as a subgroup and analysing this data set showed 87% exhibiting spatial temporal association. This leads to the conclusion that participants consistently exhibit spatial temporal association across all spatial temporal information visualisation techniques. Linear temporal progression influencing spatial temporal progression due to the orientation of writing progression of the language, such as English in which the study was conducted, was not evident in the analysis of the participant responses. Therefore it can be concluded that linear temporal progression orientation cannot be assumed based on literary written progression orientation, and that the placement of temporal objects along a horizontal line may require additional temporal cues to establish temporal progression orientation.

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Appendix A

Research Survey Questions

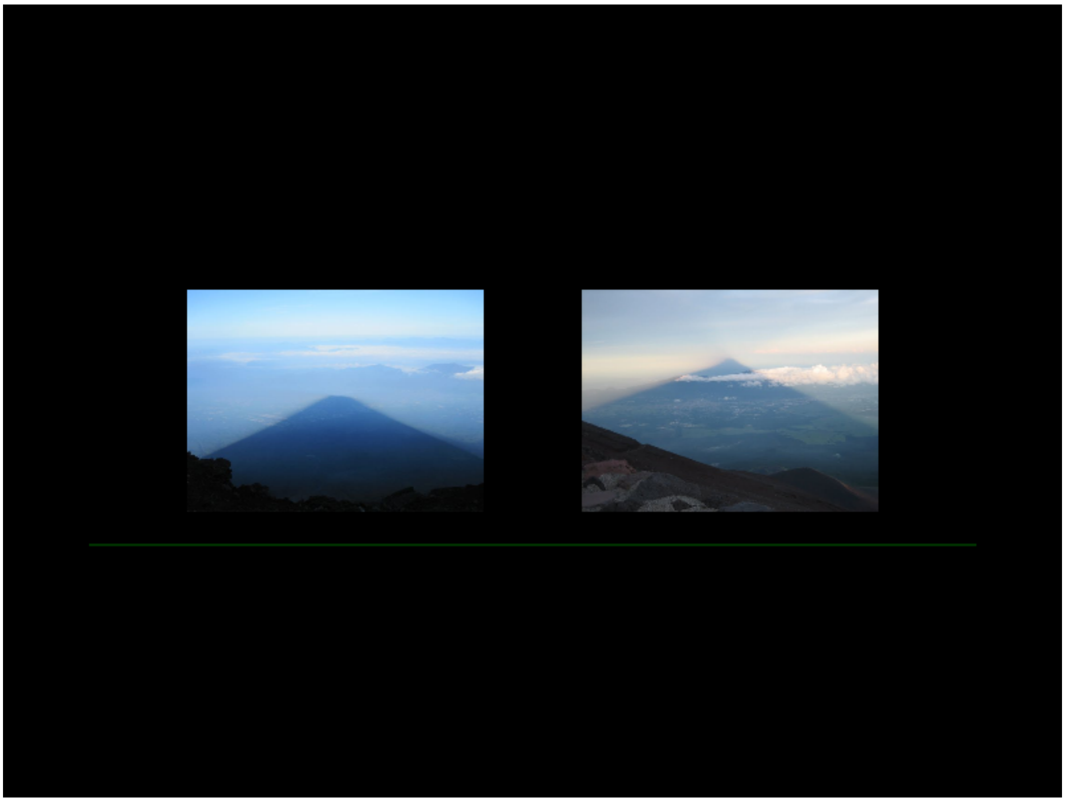
The survey question images were presented in the Internet web survey with a resolution of 800 by 600 pixels.

11 Which is the younger horse?

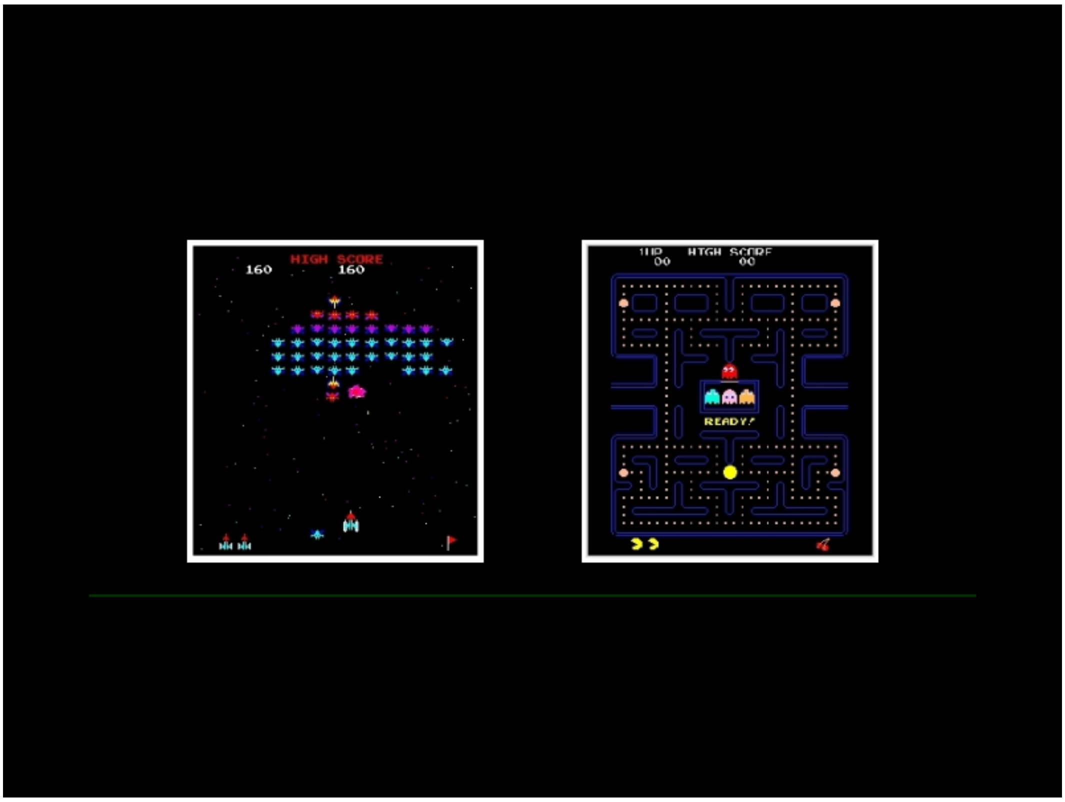
12 Which perfume bottle is the older?

13 Which dress was designed first?

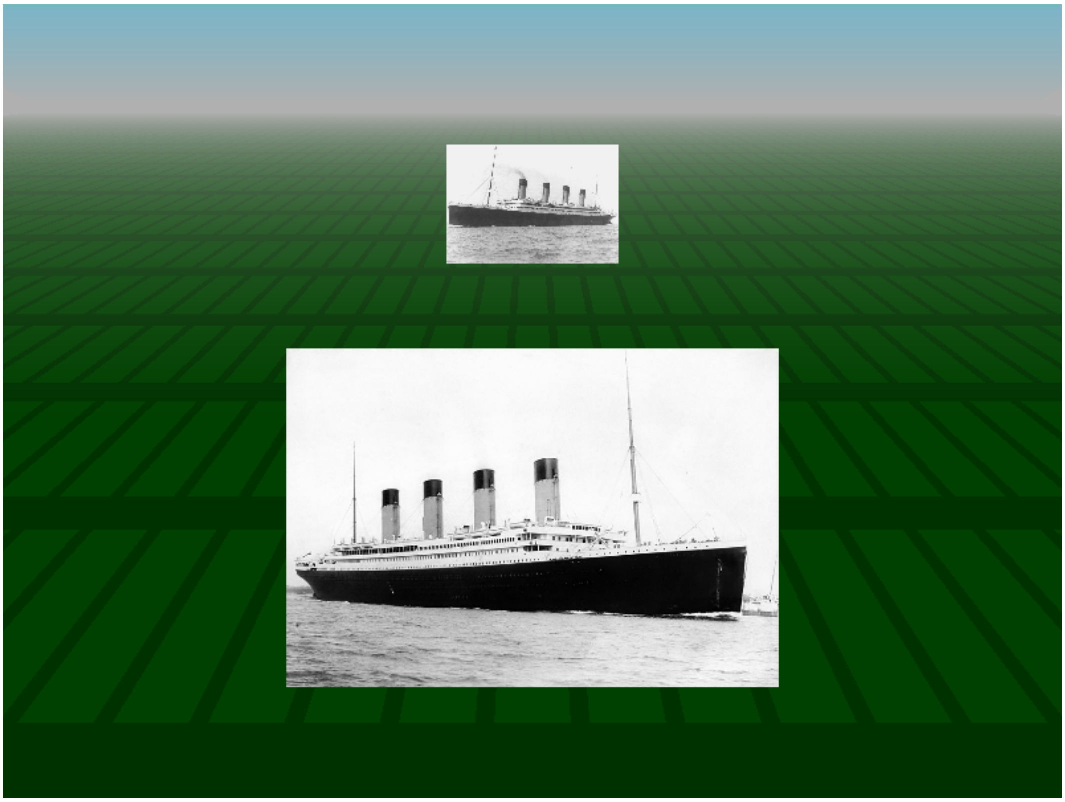
14 This is the shadow of a mountain cast at sunrise and sunset. Which is the sunset shadow?



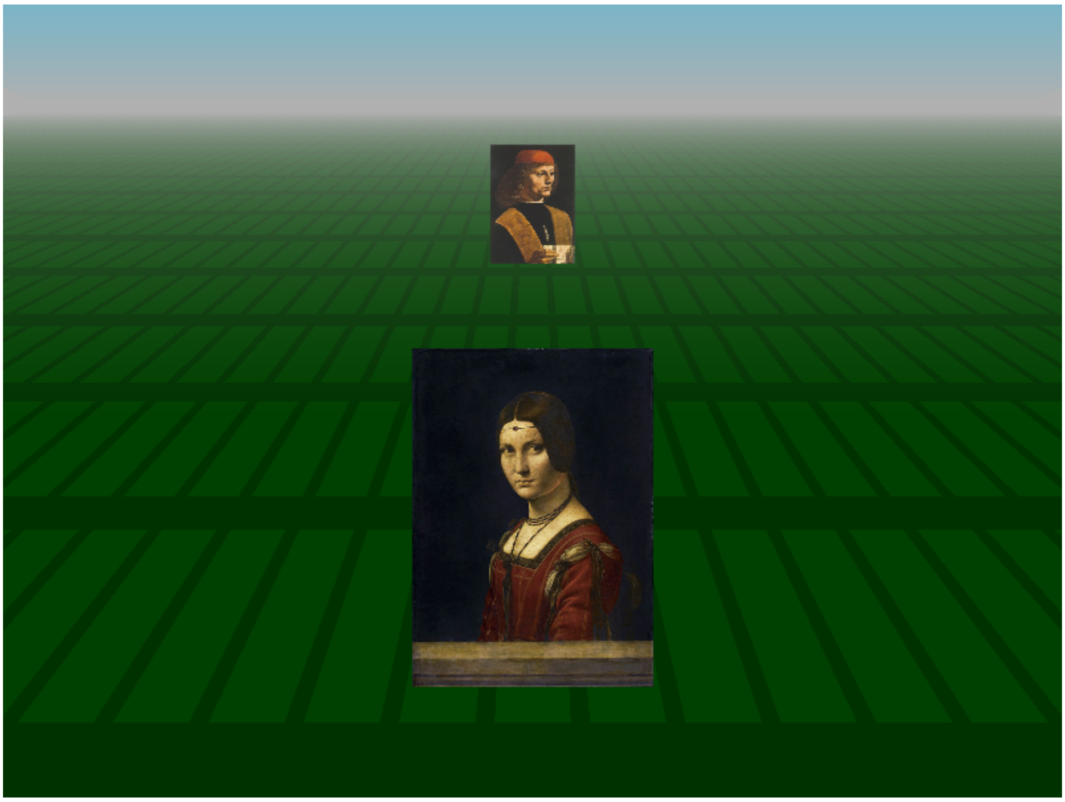
15 Which video game was released first?



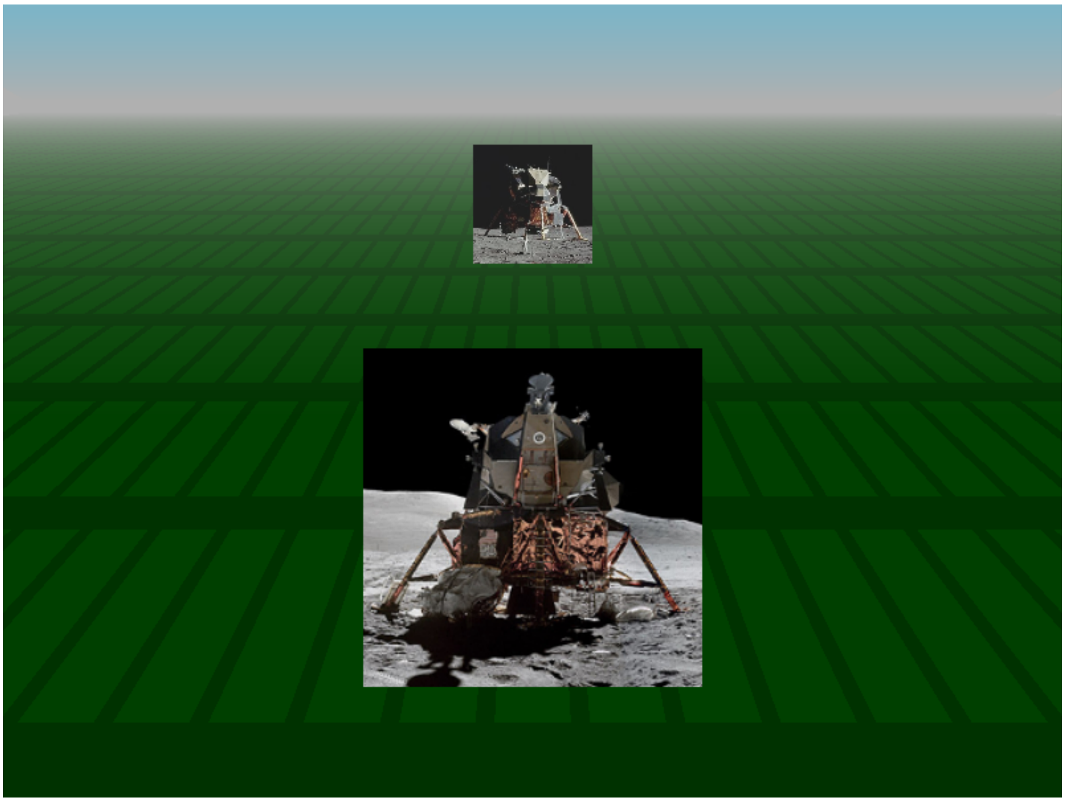
21 Which is the older ship?



22 Which painting is the older?

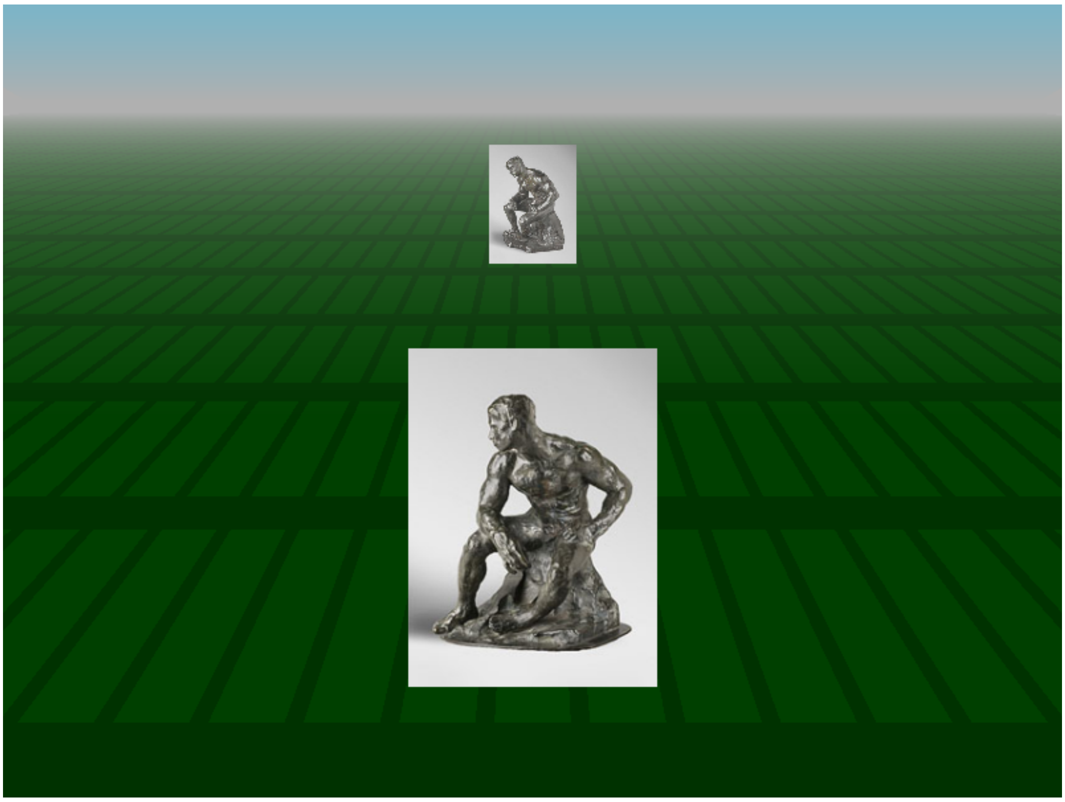


23 Which of these two lunar landers was the last to land on the moon?



24 Which Greek amphora is the younger?

25 Which bronze was cast first?



31 Which is the most recent stamp issued?

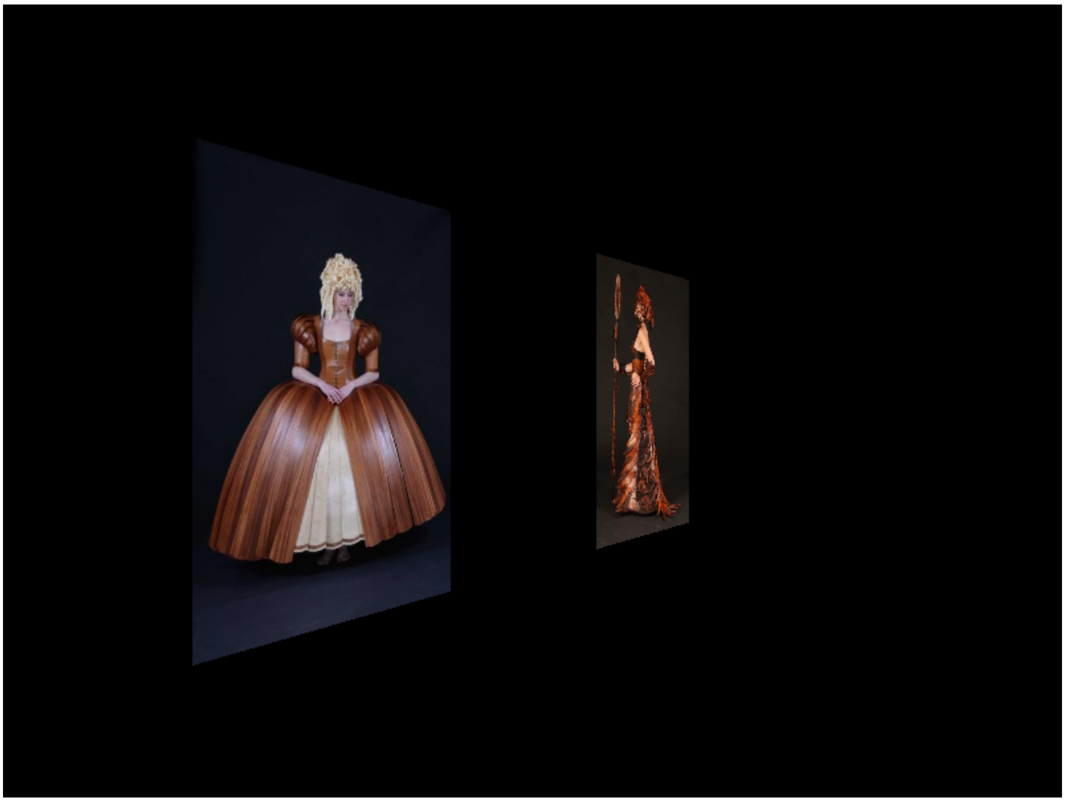
32 Which is the older of these Fabergé eggs?

33 Which is the current currency?

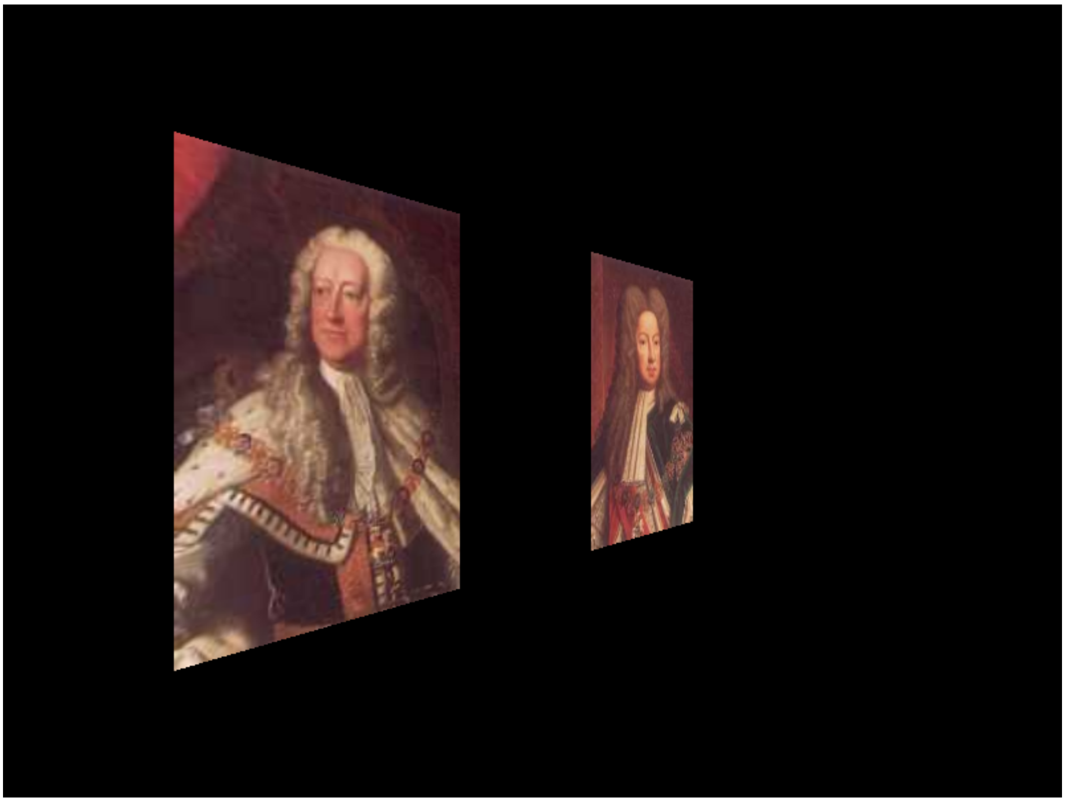
34 Which book was published first?

35 Which movie was made first?

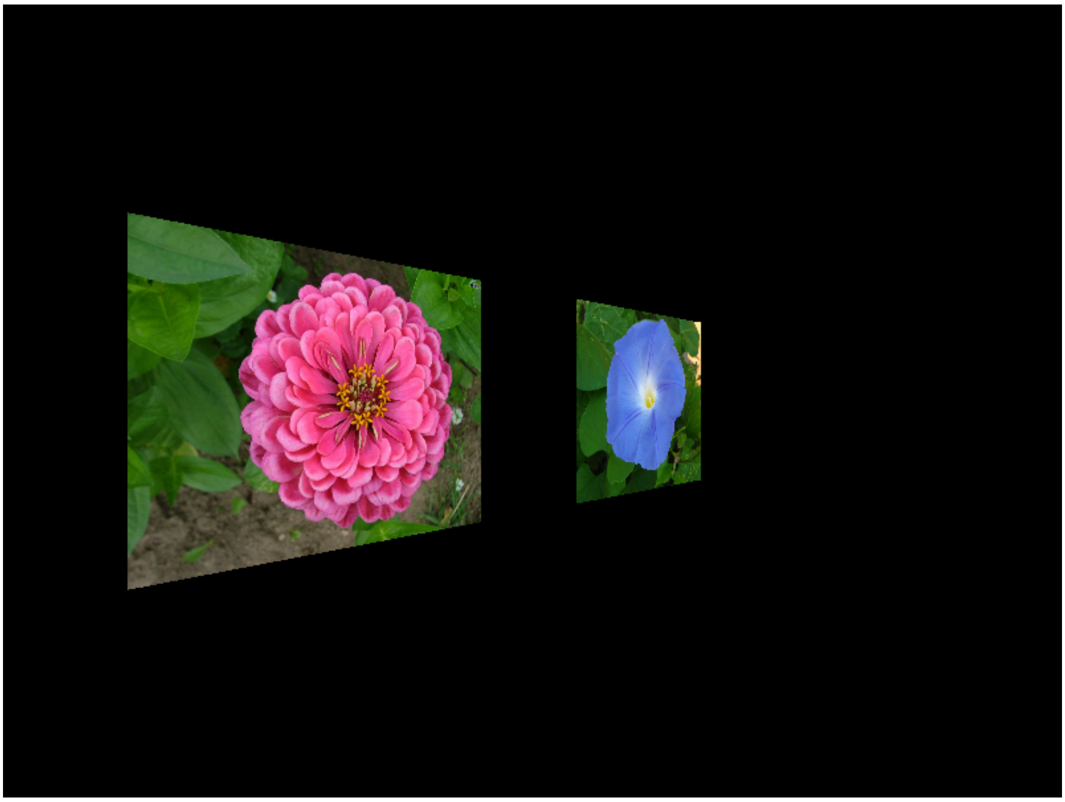
41 Which of these two pieces of wearable art was create first?



42 Which of these two kings of England reigned first?



43 Which of these two is the last to open each day?



44 Which of these two hydroelectric dams was built first?

45 Which of the two dolls is the older?

Appendix B

Ethics Consent Documentation

Application for Approval
Outline of Research or Related Activity
Ethics Committee, Faculty of Computing and Mathematical Sciences

Details of Proposed Activity

1. Identify the project

1.1 Title of Project

Temporal Visualisation

1.2 Researcher(s) name and contact information

Greg Clarke	email:	gclarke@waikato.ac.nz
	Extn:	4728
	Cell:	027 491 4998

1.3 Supervisor's name and contact information (if relevant)

Prof. Mark Apperley	email:	mapperle@waikato.ac.nz
	Extn:	4528

1.4 Anticipated date to begin data collection

20th August, 2012

1.5 Does your application involve issues of health or disability with human participants? If so, please refer to the guidelines as to whether your application needs to be submitted to the Northern Y Regional Ethics Committee.

This application does not involve issues of health or disability with human participants

2. Describe the research or related activity

2.1 Briefly outline what the project is about including your goals and anticipated benefits. Include links with a research programme, if relevant.

The goal of the project is to evaluate human perception of temporal visualizations. It has been established that temporal and spacial understanding are co-developed in human development. As spacial development is three dimensional can the visualization of temporal relationships between objects be presented in a three dimensional format and thus be immediately perceived and understood without temporal cues such as time or dates.

2.2 Briefly outline your methods.

Utilising a web based survey the participants will be presented with twenty questions each a visualisation of the temporal relationship between two objects. Five questions will utilise the common time line visualisation with a single line beneath the two objects. These five questions will be used to establish the participants left/right bias. Five questions will be visualised using strong three dimensional cues of grid lines, horizon, and depth fogging, to establish depth. These five questions will evaluate the participants perception of depth and temporal relationships and how the participant orients the two, for example, greater depth implies, older, occurring first, or vice versa. The remaining ten question will utilise visualisations using perspective as a depth cue. The object image pairs will be presented as if they are hanging on a wall either viewed as being on the left or right of the observer. These questions will test whether depth can override the left/right bias of the participant. The questions have been group randomised based on type of visualisation with additional randomising between the visualisations types to blur the boundaries between the visualisation types.

2.3 Describe plans to give participants information about the goals of the research or related activity.

The participants will be informed that the goal of the study is evaluate different visualisation techniques to portray the temporal relationship between objects.

2.4 Identify the expected outputs of this research or related activity (e.g., reports, publications, presentations).

The expected outputs of the research is a Master of Science degree thesis where the research will either support or reject the hypothesis that temporal relationships can be visualised using three dimension techniques due to co-development of spacial and temporal concepts in human development. A summary of findings will be produced consisting of the analysis of the survey results showing the relevance of using depth as a temporal cue that will be made available to participants on request.

2.5 Identify who is likely to see or hear reports or presentations arising from this research or related activity.

The resulting thesis will be available to any researcher interested in the fields of informations visualisation and/or psychology related to temporal perception,

2.6 Identify the physical location(s) for the research or related activity, the group or community to which your potential participants belong, and any private data or documents you will seek to access. Describe how you have access to the site, participants and data/documents. Identify how you obtain(ed) permission from relevant authorities/gatekeepers if appropriate and any conditions associated with access.

The study is web based therefore can be undertaken in any location where the participant can access the Internet.

3. Obtain participants' informed consent without coercion

3.1 Describe how you will select participants (e.g., special criteria or characteristics) and how many will be involved.

There is no criteria or selection procedure for participants.

3.2 State clearly whether this is an application under section 10 of the Ethical Conduct in Human Research and Related Activities Regulations: Large Random Sample Surveys.

This application is NOT being made under section 10 of the Ethical Conduct in Human Research and Related Activities Regulation: Large Random Sample Surveys.

3.3 Describe how you will invite them to participate.

The URL of the web survey will be distributed to work colleagues, friends, and acquaintances who have no prior knowledge of study topic, advertised in social media via LinkedIn and Google+, plus flyers on campus. It is expected additional participation will occur through word of mouth.

3.4 Show how you provide prospective participants with all information relevant to their decision to participate. Attach your participant information sheet, cover letter, or introduction script. See document on informed consent for recommended content. Information should include, but is not limited to:

- what you will ask them to do;

- the context in which information sheets and consent sheets will be used. When (e.g. just before the study, a week before etc), where (e.g. in a laboratory environment, in a field setting etc) and in what form (e.g. paper, email etc) information will be provided to prospective participants.
- how to refuse to answer any particular question, or withdraw any information they have provided at any time before completion of data collection;
- how and when to ask any further questions about the study or get more information.
- the form in which the findings will be disseminated and how participants can access a summary of the findings from the study when it is concluded.

3.5 Describe how you get their consent. (Attach a consent form if you use one).

The web survey introductory page concludes with a button labelled “Click Here to Start”, preceding this button is the statement 'Proceeding with the survey by clicking the "Click Here to Start" button affirms your consent to participate in the study.' A printed copy of the introductory page is attached.

3.6 Explain incentives and/or compulsion for participants to be involved in this study, including monetary payment, prizes, goods, services, or favours, either directly or indirectly.

There are no incentives or inducements to participate in the study.

4. Minimise deception

If your research or related activity involves deception – this includes incomplete information to participants -- explain the rationale. Describe how and when you will provide full information or reveal the complete truth about the research or related activity including reasons for the deception.

The research does not intend to involve deception.

5. Respect privacy and confidentiality

5.1 Explain how any publications and/or reports will have the participants’ consent.

Consent is obtained by the participant proceeding with the survey by clicking the “Click Here to Start” button which is preceded by a statement that describes the act of doing so affirms consent.

5.2 Explain how you will protect participants’ identities (or why you will not).

The web survey is completely anonymous. No personal details are collected in the survey. No cookies are deployed to the participants browser. No details about the browser, the system on which it is being used, or network details, such as the IP address of the system, are recorded. Only the answers to the questions are recorded along with the time and date the participant took part in the survey. Analysis of the data obtained by the survey will be of trends in responses and will not identify any data from a single participant.

5.3 Describe who will have access to the information/data collected from participants. Explain how you will protect or secure confidential information.

The data collected by the survey will be accessible by the researcher and supervisor listed in sections 1.2 and 1.3 respectively (see above). The data will be archived in the FCMS Data Archive with a destruction date of 13/02/2020 (see attached FCMS Data Archive Deposit Cover Sheet).

6. Minimise harm to participants

‘Harm' includes pain, stress, emotional distress, fatigue, embarrassment and exploitation.

6.1 Where participants risk change from participating in this research or related activity compared to their daily lives, identify that risk and explain how your procedures minimize the consequences.

There will be no risk to the participant.

6.2 Describe any way you are associated with participants that might influence the ethical appropriateness of you conducting this research or related activity – either favourably (e.g., same language or culture) or unfavourably (e.g., dependent relationships such as employer/employee, supervisor/worker, lecturer/student). As appropriate, describe the steps you will take to protect the participants.

There may be dependent relationships with some possible participants being work colleagues, friends, and relations, of the researcher. The researcher will excuse himself from the presence of any participant who is undertaking the survey in his proximity. The researcher will politely refuse to answer any verbal questions related to the survey before a participant takes part. Questions lodged via the email address advertised in the survey introductory and closing pages will be responded too. The researcher will maintain a professional relationship and attitude toward all participants.

6.3 Describe any possible conflicts of interest and explain how you will protect participants' interests and maintain your objectivity.

There are no conflict of interest inherent in the survey.

7. Exercise social and cultural sensitivity

7.1 Identify any areas in your research or related activity that are potentially sensitive, especially from participants' perspectives. Explain what you do to ensure your research or related activity procedures are sensitive (unlikely to be insensitive). Demonstrate familiarity with the culture as appropriate.

There are no culturally sensitive aspects in the survey. Images have been selected for their neutrality and conservative nature, Human images contained in the survey are fully clothed with no nudity. There are no political or religious images.

7.2 If the participants as a group differ from the researcher in ways relevant to the research or related activity, describe your procedures to ensure the research or related activity is culturally safe and non offensive for the participants.

The temporal visualisations presented in the survey questions have no temporal cues such as date or time that would impart a temporal bias therefore the temporal bias of the participant is not influenced by the visualisation other than how that bias can be eliminated by utilising a three dimensional space relationship with temporal understanding.
Any complaint from a participant will be immediately notified to the supervisor.

Addendum

Tools and services provided by third parties

The web survey has been constructed with tools supplied, and is hosted, by the web survey service provider www.SurveyWriter.com (SurveyWriter). All survey materials used, and data collected, by SurveyWriter web survey service is owned by the researcher (client). SurveyWriter make no claim of ownership of the survey, data collected, or any intellectual property derived from the survey and data. The data can only be accessed by the client and is protected by an administrative password only known too the client. The client may provide access to the data, or part there of, to others via a password that the client assigns. The survey and collected data can only be destroyed by the client. SurveyWriter have been provided with a copy of the Ethical Conduct in Human Research and Related Activities Regulation and have agreed to abide by the regulations. A transcript of the email agreeing to abide to the regulations follows:

Date: Fri, 27 Jul 2012 13:48:47 -0500
Message-ID: <CAH5D8qSofuPk1rcTj1TNgZ2-FpgjzccL3eQWujfrWD=hsVcsdQ@mail.gmail.com>
Subject: Re: SurveyWriter Account Information
From: Paul Vriend <prv@surveywriter.com>
To: Greg Clarke <gclarke@waikato.ac.nz>

To whom it may concern:

I have reviewed and agree to abide by the regulations contained in the
following document:

http://www.cs.waikato.ac.nz/genquery.php?linktype=link&linklist=CS_Rightbar&linkname=Ethical_Consent

Sincerely,

Paul Vriend (Partner)
www.surveywriter.com
Ravenswood Ave Unit 236. Chicago, IL 60613.

Letter granting ethics consent.

Computing and Mathematical Sciences
Rorohiko me ngā Pūtaiao Pāngarau
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Hamilton
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THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

6 August 2012

Greg Clark
C/- Department of Computer Science
THE UNIVERSITY OF WAIKATO

Dear Greg

Request for approval to conduct an on-line survey with human participants

I have considered your request to conduct a survey for your research project *Temporal Visualization* for your MSc research.

The purpose of the study is to evaluate human perception of temporal visualizations, using different visualization techniques to portray the temporal relationship between objects.

No personal details of participants will be requested during this survey therefore publications and reported results will not contain any names or any other identifying characteristics.

The procedure described in your request is acceptable.

The research participants' information sheet and consent form, meet the requirements of the University's human research ethics policies and procedures.

Yours sincerely,

Lyn Hunt
Human Research Ethics Committee
School of Computing and Mathematical Sciences

Appendix C

Programs that Generate Research Survey Images

The C++ source code files and the temporal information visualisation technique image generated.

tl.c	Time line.
tl3d.c	3D spatial environment using the spatial cues of a plane and horizon.
tl3dlw.c	Spatial 3D with a single line of temporal progression that depicts the temporal object images as if hanging on a wall to the left of the viewer.
tl3drw.c	Spatial 3D with a single line of temporal progression that depicts the temporal object images as if hanging on a wall to the right of the viewer.

```
/*====================================================================
 *
 *  Time Line       1.0             09/06/2012
 *
 *  Original:       Greg Clarke     09/06/2012
 *
 *  Modifications:
 *
 *  Objective:      Generate time line temporal information
 *                  visualisation.
 *
 *  Options:
 *
 *  Arguments:
 *
 *  Outputs:        Window containing generated image.
 *
 *====================================================================*/

#include <clutter/clutter.h>
#include <math.h>
#include <stdlib.h>

int main(int argc, char *argv[]) {

    /* Stage size */
    const gfloat STAGE_WIDTH = 800;
    const gfloat STAGE_HEIGHT = 600;

    /* Image size */
    const gfloat IMAGE_MAXIMUM_WIDTH = STAGE_WIDTH / 3;
    const gfloat IMAGE_MAXIMUM_HEIGHT = STAGE_HEIGHT / 2;

    /* Image depth */
    const gfloat TIMELINE_IMAGE_DEPTH = 0 - 100;

    /* Timeline description */
    const gfloat TIMELINE_HEIGHT = STAGE_HEIGHT * 0.005;
    const gfloat TIMELINE_LENGTH = STAGE_WIDTH;
    const gfloat TIMELINE_IMAGE_OFFSET = STAGE_HEIGHT * 0.05;

    /* Initialise colour pallet */
    ClutterColor stageColour = { 0x00, 0x00, 0x00, 0xff };      // black
    ClutterColor timeLineColour = { 0x00, 0x32, 0x00, 0xff };   // dark green

    /* Initialise clutter environment */
    ClutterInitError clutterInitResult = clutter_init (&argc, &argv);
    if (clutterInitResult != CLUTTER_INIT_SUCCESS) {
      g_print("Clutter initialisation error : %d\n", (int) clutterInitResult);
    }

    /* Initialise and define stage */
    ClutterActor *stage = clutter_stage_get_default();
```

```
    clutter_actor_set_size(stage, STAGE_WIDTH, STAGE_HEIGHT);
    clutter_stage_set_color(CLUTTER_STAGE(stage), &stageColour);

    /* Get images */
    ClutterActor *leftImage = clutter_texture_new_from_file("leftImage.jpg", NULL);
    ClutterActor *rightImage = clutter_texture_new_from_file("rightImage.jpg", NULL);

    /* Calculate scale */
    gfloat scale = 1.0;
    gfloat imageMaximumWidth = clutter_actor_get_width(leftImage);
    if (clutter_actor_get_width(leftImage) < clutter_actor_get_width(rightImage)) {
        imageMaximumWidth = clutter_actor_get_width(rightImage);
    }
    gfloat imageMaximumHeight = clutter_actor_get_height(leftImage);
    if (clutter_actor_get_height(leftImage) < clutter_actor_get_height(rightImage)) {
        imageMaximumHeight = clutter_actor_get_height(rightImage);
    }
    scale = IMAGE_MAXIMUM_WIDTH / imageMaximumWidth;
    if (imageMaximumHeight * scale > IMAGE_MAXIMUM_HEIGHT) {
        scale = IMAGE_MAXIMUM_HEIGHT / imageMaximumHeight;
    }

    /* Scale images */
    clutter_actor_set_width(leftImage, clutter_actor_get_width(leftImage) * scale);
    clutter_actor_set_height(leftImage, clutter_actor_get_height(leftImage) * scale);
    clutter_actor_set_width(rightImage, clutter_actor_get_width(rightImage) * scale);
    clutter_actor_set_height(rightImage, clutter_actor_get_height(rightImage) * scale);

    /* Calculate image separation */
    gfloat imageSeparation = (clutter_actor_get_width(stage) - clutter_actor_get_width(leftImage) - clutter_actor_get_width(rightImage)) / 3;

    /* Calculate image X positions */
    gfloat leftImageXposition = (clutter_actor_get_width(stage) - clutter_actor_get_width(leftImage) - clutter_actor_get_width(rightImage) - imageSeparation) / 2;
    gfloat rightImageXposition = leftImageXposition + clutter_actor_get_width(leftImage) + imageSeparation;

    /* Calculate image Y position */
    gfloat imageYposition = 0;
    if (clutter_actor_get_height(leftImage) > clutter_actor_get_height(rightImage)) {
        imageYposition = clutter_actor_get_height(stage) - (clutter_actor_get_height(stage) - clutter_actor_get_height(leftImage)) / 2;
    } else {
        imageYposition = clutter_actor_get_height(stage) - (clutter_actor_get_height(stage) - clutter_actor_get_height(rightImage)) / 2;
    }

    /* Add left image to stage */
    clutter_actor_set_anchor_point(leftImage, 0, clutter_actor_get_height(leftImage));
    clutter_actor_set_position(leftImage, leftImageXposition, imageYposition);
    clutter_actor_set_depth(leftImage, TIMELINE_IMAGE_DEPTH);
    clutter_container_add_actor(CLUTTER_CONTAINER(stage), leftImage);
    clutter_actor_show(leftImage);

    /* Add right image to stage */
    clutter_actor_set_anchor_point(rightImage, 0, clutter_actor_get_height(rightImage));
    clutter_actor_set_position(rightImage, rightImageXposition, imageYposition);
```

```
    clutter_actor_set_depth(rightImage, TIMELINE_IMAGE_DEPTH);
    clutter_container_add_actor(CLUTTER_CONTAINER(stage), rightImage);
    clutter_actor_show(rightImage);

    /* Add line to stage */
    ClutterActor *timeLine;
    timeLine = clutter_rectangle_new_with_color(&timeLineColour);
    clutter_actor_set_width(timeLine, TIMELINE_LENGTH);
    clutter_actor_set_height(timeLine, TIMELINE_HEIGHT);
    clutter_actor_set_anchor_point(timeLine, clutter_actor_get_width(timeLine) / 2, clutter_actor_get_height(timeLine) / 2);
    clutter_actor_set_position(timeLine, clutter_actor_get_width(stage) / 2, imageYposition + TIMELINE_IMAGE_OFFSET);
    clutter_actor_set_depth(timeLine, TIMELINE_IMAGE_DEPTH);
    clutter_container_add_actor(CLUTTER_CONTAINER(stage), timeLine);
    clutter_actor_show(timeLine);

    /* Display stage */
    clutter_actor_show(stage);

    /* Time Line */
    clutter_main();

    /* Report image details */
    gfloat left = 0.0;
    gfloat top = 0.0;
    gfloat width = 0.0;
    gfloat height = 0.0;
    clutter_actor_get_transformed_position(leftImage, &left, &top);
    clutter_actor_get_transformed_size(leftImage, &width, &height);
    printf("\n");
    printf(" width = %3d\n", (int) (width + 0.5));
    printf("height = %3d\n", (int) (height + 0.5));
    printf("  left = %3d  ->  %3d\n", (int) (left + 0.5), (int) (left + 10.5));
    printf("   top = %3d  ->  %3d\n", (int) (top + 0.5), (int) (top + 100.5));
    clutter_actor_get_transformed_position(rightImage, &left, &top);
    clutter_actor_get_transformed_size(rightImage, &width, &height);
    printf("\n");
    printf(" width = %3d\n", (int) (width + 0.5));
    printf("height = %3d\n", (int) (height + 0.5));
    printf("  left = %3d  ->  %3d\n", (int) (left + 0.5), (int) (left + 10.5));
    printf("   top = %3d  ->  %3d\n", (int) (top + 0.5), (int) (top + 100.5));

    return EXIT_SUCCESS;
}
```

```
/*====================================================================
 *
 *  3D Time Line    1.0             21/05/2012
 *
 *  Original:       Greg Clarke     21/05/2012
 *
 *  Modifications:
 *
 *  Objective:      Generate spatial temporal information visualisation
 *                  with 3D spatial environment cues.
 *
 *  Options:
 *
 *  Arguments:
 *
 *  Outputs:        Window containing generated image.
 *
 *====================================================================*/

#include <clutter/clutter.h>
#include <math.h>
#include <stdlib.h>

int main(int argc, char *argv[]) {

    /* Stage size */
    const gfloat STAGE_WIDTH = 800;
    const gfloat STAGE_HEIGHT = 600;

    /* Image size */
    const gfloat IMAGE_MAXIMUM_WIDTH = STAGE_WIDTH / 1.5;
    const gfloat IMAGE_MAXIMUM_HEIGHT = STAGE_HEIGHT / 2;

    /* Grid description */
    const gfloat GRID_SIZE_RATIO_FACTOR = 4;
    const gfloat GRID_SPACING_WIDTH = 64;
    const gfloat GRID_SPACING_DEPTH = GRID_SPACING_WIDTH * GRID_SIZE_RATIO_FACTOR;
    const gfloat GRID_LINE_WIDTH = 16;
    const gfloat GRID_CELL_WIDTH = GRID_SPACING_WIDTH + GRID_LINE_WIDTH;
    const gfloat GRID_CELL_DEPTH = GRID_SPACING_DEPTH + GRID_LINE_WIDTH * GRID_SIZE_RATIO_FACTOR;
    const int GRID_WIDTH_LINE_COUNT = 96;
    const int GRID_DEPTH_LINE_COUNT = (int) GRID_WIDTH_LINE_COUNT / GRID_SIZE_RATIO_FACTOR * 0.75;
    const gfloat GRID_LINE_WIDTH_LENGTH = GRID_CELL_WIDTH * (GRID_WIDTH_LINE_COUNT - 1) + GRID_LINE_WIDTH;
    const gfloat GRID_LINE_DEPTH_LENGTH = GRID_CELL_DEPTH * (GRID_DEPTH_LINE_COUNT - 1) + GRID_LINE_WIDTH;

    /* Camera point of view adjustment */
    const gfloat PI = atan(1.0) * 4;
    const gfloat CAMERA_POSITION_ADJUSTED_PLANE_ANGLE = 28;
    const gfloat CAMERA_POSITION_ADJUSTED_PLANE_ANGLE_IN_RADIANS = CAMERA_POSITION_ADJUSTED_PLANE_ANGLE * PI / 180;
    const gfloat DEPTH_FACTOR = cos(CAMERA_POSITION_ADJUSTED_PLANE_ANGLE_IN_RADIANS);
    const gfloat HEIGHT_FACTOR = sin(CAMERA_POSITION_ADJUSTED_PLANE_ANGLE_IN_RADIANS);
    const gfloat CAMERA_POSITION_ADJUSTED_PLANE_ROTATION = -90 - CAMERA_POSITION_ADJUSTED_PLANE_ANGLE;
```

```
/* Sky rotation to assist depth cue */
const gfloat SKY_ROTATION = -90;

/* Image depth */
const gfloat FOREGROUND_IMAGE_DEPTH_POSITION = 100;
const gfloat BACKGROUND_IMAGE_DEPTH_POSITION = FOREGROUND_IMAGE_DEPTH_POSITION + GRID_CELL_DEPTH * 4;


/*=================================================================
 *
 * Calculate true depth on inclined plane for camera view adjustment.
 *
 *=================================================================*/
gfloat cameraPositionAdjustedDepth(gfloat depth) {
    return(depth * DEPTH_FACTOR);
}

/*=================================================================
 *
 * Calculate true height on inclined plane for camera view adjustment.
 *
 *=================================================================*/
gfloat cameraPositionAdjustedHeight(gfloat height) {
    return(height * HEIGHT_FACTOR);
}

/* Initialise colour pallet */
ClutterColor stageColour = { 0xb0, 0xb0, 0xb0, 0xff };      // grey
ClutterColor surfaceColour = { 0x00, 0x40, 0x00, 0xff };    // green
ClutterColor gridLineColour = { 0x00, 0x32, 0x00, 0xff };   // dark green
ClutterColor skyColour = { 0x00, 0xbf, 0xff, 0xff };        // deep skyblue

/* Initialise clutter environment */
ClutterInitError clutterInitResult = clutter_init (&argc, &argv);
if (clutterInitResult != CLUTTER_INIT_SUCCESS) {
  g_print("Clutter initialisation error : %d\n", (int) clutterInitResult);
}

/* Initialise and define stage */
ClutterActor *stage = clutter_stage_get_default();
clutter_actor_set_size(stage, STAGE_WIDTH, STAGE_HEIGHT);
clutter_stage_set_color(CLUTTER_STAGE(stage), &stageColour);

/* Get stage perspective setting */
ClutterPerspective stagePerspective;
clutter_stage_get_perspective(CLUTTER_STAGE(stage), &stagePerspective);

/* Set fog region for depth cuing */
ClutterFog fogZone = {stagePerspective.z_far * 0.1, stagePerspective.z_far * 0.5};
clutter_stage_set_use_fog(CLUTTER_STAGE(stage), TRUE);
clutter_stage_set_fog(CLUTTER_STAGE(stage), &fogZone);

/* Create sky and add to stage */
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    ClutterActor *sky = clutter_rectangle_new_with_color(&skyColour);
    clutter_actor_set_width(sky, GRID_LINE_WIDTH_LENGTH);
    clutter_actor_set_height(sky, GRID_LINE_DEPTH_LENGTH);
    clutter_actor_set_anchor_point(sky, clutter_actor_get_width(sky) / 2, clutter_actor_get_height(sky));
    clutter_actor_set_position(sky, clutter_actor_get_width(stage) / 2, clutter_actor_get_height(stage) - cameraPositionAdjustedHeight(clutter_actor_get_height(sky)))
;
    clutter_actor_set_depth(sky, cameraPositionAdjustedDepth(0 - clutter_actor_get_height(sky)));
    clutter_actor_set_rotation(sky, CLUTTER_X_AXIS, SKY_ROTATION, 0, 0, 0);
    clutter_container_add_actor(CLUTTER_CONTAINER(stage), sky);
    clutter_actor_show(sky);

    /* Create a plane with an array of grid lines and add to stage */
    ClutterActor *plane = clutter_group_new();
    ClutterActor *surface = clutter_rectangle_new_with_color(&surfaceColour);
    clutter_actor_set_width(surface, GRID_LINE_WIDTH_LENGTH);
    clutter_actor_set_height(surface, GRID_LINE_DEPTH_LENGTH);
    clutter_container_add_actor(CLUTTER_CONTAINER(plane), surface);
    ClutterActor *gridDepthLine[GRID_WIDTH_LINE_COUNT];
    ClutterActor *gridWidthLine[GRID_DEPTH_LINE_COUNT];
    int x;
    for (x = 0; x < GRID_WIDTH_LINE_COUNT; x++) {
        gridDepthLine[x] = clutter_rectangle_new_with_color(&gridLineColour);
        clutter_actor_set_width(gridDepthLine[x], GRID_LINE_WIDTH);
        clutter_actor_set_height(gridDepthLine[x], GRID_LINE_DEPTH_LENGTH);
        clutter_actor_set_position(gridDepthLine[x], GRID_CELL_WIDTH * x, 0);
        clutter_container_add_actor(CLUTTER_CONTAINER(plane), gridDepthLine[x]);
    }
    int y;
    for (y = 0; y < GRID_DEPTH_LINE_COUNT; y++) {
        gridWidthLine[y] = clutter_rectangle_new_with_color(&gridLineColour);
        clutter_actor_set_width(gridWidthLine[y], GRID_LINE_WIDTH_LENGTH);
        clutter_actor_set_height(gridWidthLine[y], GRID_LINE_WIDTH * GRID_SIZE_RATIO_FACTOR);
        clutter_actor_set_position(gridWidthLine[y],0 ,GRID_CELL_DEPTH * y);
        clutter_container_add_actor(CLUTTER_CONTAINER(plane), gridWidthLine[y]);
    }
    clutter_actor_set_anchor_point(plane, clutter_actor_get_width(plane) / 2, clutter_actor_get_height(plane));
    clutter_actor_set_position(plane, clutter_actor_get_width(stage) / 2, clutter_actor_get_height(stage) - cameraPositionAdjustedHeight(clutter_actor_get_height(plan
e)));
    clutter_actor_set_depth(plane, cameraPositionAdjustedDepth(0 - clutter_actor_get_height(plane)));
    clutter_actor_set_rotation(plane, CLUTTER_X_AXIS, CAMERA_POSITION_ADJUSTED_PLANE_ROTATION, 0, 0, 0);
    clutter_container_add_actor(CLUTTER_CONTAINER(stage), plane);
    clutter_actor_show(plane);

    /* Get images */
    ClutterActor *backgroundImage = clutter_texture_new_from_file("backgroundImage.jpg", NULL);
    ClutterActor *foregroundImage = clutter_texture_new_from_file("foregroundImage.jpg", NULL);

    /* Calculate scale */
    gfloat scale = 1.0;
    gfloat imageMaximumWidth = clutter_actor_get_width(backgroundImage);
    if (clutter_actor_get_width(backgroundImage) < clutter_actor_get_width(foregroundImage)) {
        imageMaximumWidth = clutter_actor_get_width(foregroundImage);
    }
```

```c
    gfloat imageMaximumHeight = clutter_actor_get_height(backgroundImage);
    if (clutter_actor_get_height(backgroundImage) < clutter_actor_get_height(foregroundImage)) {
        imageMaximumHeight = clutter_actor_get_height(foregroundImage);
    }
    scale = IMAGE_MAXIMUM_WIDTH / imageMaximumWidth;
    if (imageMaximumHeight * scale > IMAGE_MAXIMUM_HEIGHT) {
        scale = IMAGE_MAXIMUM_HEIGHT / imageMaximumHeight;
    }

    /* Scale images */
    clutter_actor_set_width(backgroundImage, clutter_actor_get_width(backgroundImage) * scale);
    clutter_actor_set_height(backgroundImage, clutter_actor_get_height(backgroundImage) * scale);
    clutter_actor_set_width(foregroundImage, clutter_actor_get_width(foregroundImage) * scale);
    clutter_actor_set_height(foregroundImage, clutter_actor_get_height(foregroundImage) * scale);

    /* Add background image to stage  */
    clutter_actor_set_anchor_point(backgroundImage, clutter_actor_get_width(backgroundImage) / 2, clutter_actor_get_height(backgroundImage));
    clutter_actor_set_position(backgroundImage, clutter_actor_get_width(stage) / 2, clutter_actor_get_height(stage) - cameraPositionAdjustedHeight(BACKGROUND_IMAGE_DE
PTH_POSITION));
    clutter_actor_set_depth(backgroundImage, cameraPositionAdjustedDepth(0 - BACKGROUND_IMAGE_DEPTH_POSITION));
    clutter_container_add_actor(CLUTTER_CONTAINER(stage), backgroundImage);
    clutter_actor_show(backgroundImage);

    /* Add foreground image to stage  */
    clutter_actor_set_anchor_point(foregroundImage, clutter_actor_get_width(foregroundImage) / 2, clutter_actor_get_height(foregroundImage));
    clutter_actor_set_position(foregroundImage, clutter_actor_get_width(stage) / 2, clutter_actor_get_height(stage) - cameraPositionAdjustedHeight(FOREGROUND_IMAGE_DE
PTH_POSITION));
    clutter_actor_set_depth(foregroundImage, cameraPositionAdjustedDepth(0 - FOREGROUND_IMAGE_DEPTH_POSITION));
    clutter_container_add_actor(CLUTTER_CONTAINER(stage), foregroundImage);
    clutter_actor_show(foregroundImage);

    /* Display stage */
    clutter_actor_show(stage);

    /* 3D Time Line */
    clutter_main();

    /* Report image details */
    gfloat left = 0.0;
    gfloat top = 0.0;
    gfloat width = 0.0;
    gfloat height = 0.0;
    clutter_actor_get_transformed_position(backgroundImage, &left, &top);
    clutter_actor_get_transformed_size(backgroundImage, &width, &height);
    printf("\n");
    printf(" width = %3d\n", (int) (width + 0.5));
    printf("height = %3d\n", (int) (height + 0.5));
    printf("  left = %3d  ->  %3d\n", (int) (left + 0.5), (int) (left + 10.5));
    printf("   top = %3d  ->  %3d\n", (int) (top + 0.5), (int) (top + 100.5));
    clutter_actor_get_transformed_position(foregroundImage, &left, &top);
    clutter_actor_get_transformed_size(foregroundImage, &width, &height);
    printf("\n");
    printf(" width = %3d\n", (int) (width + 0.5));
```

```
    printf("height = %3d\n", (int) (height + 0.5));
    printf("  left = %3d  ->  %3d\n", (int) (left + 0.5), (int) (left + 10.5));
    printf("   top = %3d  ->  %3d\n", (int) (top + 0.5), (int) (top + 100.5));

    return EXIT_SUCCESS;
}
```

```
/*======================================================================
 *
 *  Time Line 3D Left Wall  1.0     06/06/2012
 *
 *  Original:       Greg Clarke     06/06/2012
 *
 *  Modifications:
 *
 *  Objective:      Generate spatial temporal information visualisation
 *                  with temporal object images hanging on a wall to
 *                  the left of the viewer.
 *
 *  Options:
 *
 *  Arguments:
 *
 *  Outputs:        Window containing generated image.
 *
 *=====================================================================*/

#include <clutter/clutter.h>
#include <math.h>
#include <stdlib.h>

int main(int argc, char *argv[]) {

    /* Stage size */
    const gfloat STAGE_WIDTH = 800;
    const gfloat STAGE_HEIGHT = 600;

    /* Image size */
    const gfloat IMAGE_MAXIMUM_WIDTH = STAGE_WIDTH / 3;
    const gfloat IMAGE_MAXIMUM_HEIGHT = STAGE_HEIGHT / 2;

    /* Image depth */
    const gfloat IMAGE_DEPTH = 0 - 100;

    /* Wall rotation */
    const gfloat WALL_ROTATION = 50;

    /* Initialise colour pallet */
    ClutterColor stageColour = { 0x00, 0x00, 0x00, 0xff };      // black

    /* Initialise clutter environment */
    ClutterInitError clutterInitResult = clutter_init (&argc, &argv);
    if (clutterInitResult != CLUTTER_INIT_SUCCESS) {
      g_print("Clutter initialisation error : %d\n", (int) clutterInitResult);
    }

    /* Initialise and define stage */
    ClutterActor *stage = clutter_stage_get_default();
    clutter_actor_set_size(stage, STAGE_WIDTH, STAGE_HEIGHT);
    clutter_stage_set_color(CLUTTER_STAGE(stage), &stageColour);
```

```
    /* Create a wall */
    ClutterActor *wall = clutter_group_new();

    /* Get images */
    ClutterActor *foregroundImage = clutter_texture_new_from_file("foregroundImage.jpg", NULL);
    ClutterActor *backgroundImage = clutter_texture_new_from_file("backgroundImage.jpg", NULL);

    /* Calculate scale */
    gfloat scale = 1.0;
    gfloat imageMaximumWidth = clutter_actor_get_width(backgroundImage);
    if (clutter_actor_get_width(backgroundImage) < clutter_actor_get_width(foregroundImage)) {
        imageMaximumWidth = clutter_actor_get_width(foregroundImage);
    }
    gfloat imageMaximumHeight = clutter_actor_get_height(backgroundImage);
    if (clutter_actor_get_height(backgroundImage) < clutter_actor_get_height(foregroundImage)) {
        imageMaximumHeight = clutter_actor_get_height(foregroundImage);
    }
    scale = IMAGE_MAXIMUM_WIDTH / imageMaximumWidth;
    if (imageMaximumHeight * scale > IMAGE_MAXIMUM_HEIGHT) {
        scale = IMAGE_MAXIMUM_HEIGHT / imageMaximumHeight;
    }

    /* Scale images */
    clutter_actor_set_width(backgroundImage, clutter_actor_get_width(backgroundImage) * scale);
    clutter_actor_set_height(backgroundImage, clutter_actor_get_height(backgroundImage) * scale);
    clutter_actor_set_width(foregroundImage, clutter_actor_get_width(foregroundImage) * scale);
    clutter_actor_set_height(foregroundImage, clutter_actor_get_height(foregroundImage) * scale);

    /* Calculate image separation */
    gfloat imageSeparation = (clutter_actor_get_width(stage) - clutter_actor_get_width(foregroundImage) - clutter_actor_get_width(backgroundImage)) / 2;

    /* Calculate image X positions */
    gfloat foregroundImageXposition = 0;
    gfloat backgroundImageXposition = clutter_actor_get_width(foregroundImage) + imageSeparation;

    /* Calculate image Y position */
    gfloat imageYposition = 0;
    if (clutter_actor_get_height(foregroundImage) > clutter_actor_get_height(backgroundImage)) {
        imageYposition = clutter_actor_get_height(stage) - (clutter_actor_get_height(stage) - clutter_actor_get_height(foregroundImage)) / 2;
    } else {
        imageYposition = clutter_actor_get_height(stage) - (clutter_actor_get_height(stage) - clutter_actor_get_height(backgroundImage)) / 2;
    }

    /* Add background image to wall */
    clutter_actor_set_anchor_point(backgroundImage, 0, clutter_actor_get_height(backgroundImage));
    clutter_actor_set_position(backgroundImage, backgroundImageXposition, imageYposition);
    clutter_container_add_actor(CLUTTER_CONTAINER(wall), backgroundImage);

    /* Add foreground image to wall */
    clutter_actor_set_anchor_point(foregroundImage, 0, clutter_actor_get_height(foregroundImage));
    clutter_actor_set_position(foregroundImage, foregroundImageXposition, imageYposition);
    clutter_container_add_actor(CLUTTER_CONTAINER(wall), foregroundImage);
```

```
    /* Add wall to stage */
    clutter_actor_set_depth(wall, IMAGE_DEPTH);
    clutter_actor_set_rotation(wall, CLUTTER_Y_AXIS, WALL_ROTATION, 0, 0, 0);
    clutter_actor_set_anchor_point(wall, clutter_actor_get_width(wall) / 2, 0);
    clutter_actor_set_position(wall, clutter_actor_get_width(stage) / 2, 0);
    clutter_container_add_actor(CLUTTER_CONTAINER(stage), wall);
    clutter_actor_show(wall);

    /* Display stage */
    clutter_actor_show(stage);

    /* Time Line 3D Left Wall */
    clutter_main();

    /* Report image details */
    gfloat left = 0.0;
    gfloat top = 0.0;
    gfloat width = 0.0;
    gfloat height = 0.0;
    clutter_actor_get_transformed_position(backgroundImage, &left, &top);
    clutter_actor_get_transformed_size(backgroundImage, &width, &height);
    printf("\n");
    printf(" width = %3d\n", (int) (width + 0.5));
    printf("height = %3d\n", (int) (height + 0.5));
    printf("  left = %3d  ->  %3d\n", (int) (left + 0.5), (int) (left + 10.5));
    printf("   top = %3d  ->  %3d\n", (int) (top + 0.5), (int) (top + 100.5));
    clutter_actor_get_transformed_position(foregroundImage, &left, &top);
    clutter_actor_get_transformed_size(foregroundImage, &width, &height);
    printf("\n");
    printf(" width = %3d\n", (int) (width + 0.5));
    printf("height = %3d\n", (int) (height + 0.5));
    printf("  left = %3d  ->  %3d\n", (int) (left + 0.5), (int) (left + 10.5));
    printf("   top = %3d  ->  %3d\n", (int) (top + 0.5), (int) (top + 100.5));

    return EXIT_SUCCESS;
}
```

```
/*======================================================================
 *
 *  Time Line 3D Right Wall 1.0     07/06/2012
 *
 *  Original:       Greg Clarke     07/06/2012
 *
 *  Modifications:
 *
 *  Objective:      Generate spatial temporal information visualisation
 *                  with temporal object images hanging on a wall to
 *                  the right of the viewer.
 *
 *  Options:
 *
 *  Arguments:
 *
 *  Outputs:        Window containing generated image.
 *
 *=====================================================================*/

#include <clutter/clutter.h>
#include <math.h>
#include <stdlib.h>

int main(int argc, char *argv[]) {

    /* Stage size */
    const gfloat STAGE_WIDTH = 800;
    const gfloat STAGE_HEIGHT = 600;

    /* Image size */
    const gfloat IMAGE_MAXIMUM_WIDTH = STAGE_WIDTH / 3;
    const gfloat IMAGE_MAXIMUM_HEIGHT = STAGE_HEIGHT / 2;

    /* Image depth */
    const gfloat IMAGE_DEPTH = 0 - 100;

    /* Wall rotation */
    const gfloat WALL_ROTATION = 0 - 50;

    /* Initialise colour pallet */
    ClutterColor stageColour = { 0x00, 0x00, 0x00, 0xff };      // black

    /* Initialise clutter environment */
    ClutterInitError clutterInitResult = clutter_init (&argc, &argv);
    if (clutterInitResult != CLUTTER_INIT_SUCCESS) {
      g_print("Clutter initialisation error : %d\n", (int) clutterInitResult);
    }

    /* Initialise and define stage */
    ClutterActor *stage = clutter_stage_get_default();
    clutter_actor_set_size(stage, STAGE_WIDTH, STAGE_HEIGHT);
    clutter_stage_set_color(CLUTTER_STAGE(stage), &stageColour);
```

```
    /* Create a wall */
    ClutterActor *wall = clutter_group_new();

    /* Get images */
    ClutterActor *foregroundImage = clutter_texture_new_from_file("foregroundImage.jpg", NULL);
    ClutterActor *backgroundImage = clutter_texture_new_from_file("backgroundImage.jpg", NULL);

    /* Calculate scale */
    gfloat scale = 1.0;
    gfloat imageMaximumWidth = clutter_actor_get_width(backgroundImage);
    if (clutter_actor_get_width(backgroundImage) < clutter_actor_get_width(foregroundImage)) {
        imageMaximumWidth = clutter_actor_get_width(foregroundImage);
    }
    gfloat imageMaximumHeight = clutter_actor_get_height(backgroundImage);
    if (clutter_actor_get_height(backgroundImage) < clutter_actor_get_height(foregroundImage)) {
        imageMaximumHeight = clutter_actor_get_height(foregroundImage);
    }
    scale = IMAGE_MAXIMUM_WIDTH / imageMaximumWidth;
    if (imageMaximumHeight * scale > IMAGE_MAXIMUM_HEIGHT) {
        scale = IMAGE_MAXIMUM_HEIGHT / imageMaximumHeight;
    }

    /* Scale images */
    clutter_actor_set_width(backgroundImage, clutter_actor_get_width(backgroundImage) * scale);
    clutter_actor_set_height(backgroundImage, clutter_actor_get_height(backgroundImage) * scale);
    clutter_actor_set_width(foregroundImage, clutter_actor_get_width(foregroundImage) * scale);
    clutter_actor_set_height(foregroundImage, clutter_actor_get_height(foregroundImage) * scale);

    /* Calculate image separation */
    gfloat imageSeparation = (clutter_actor_get_width(stage) - clutter_actor_get_width(foregroundImage) - clutter_actor_get_width(backgroundImage)) / 2;

    /* Calculate image X positions */
    gfloat backgroundImageXposition = 0;
    gfloat foregroundImageXposition = clutter_actor_get_width(backgroundImage) + imageSeparation;

    /* Calculate image Y position */
    gfloat imageYposition = 0;
    if (clutter_actor_get_height(foregroundImage) > clutter_actor_get_height(backgroundImage)) {
        imageYposition = clutter_actor_get_height(stage) - (clutter_actor_get_height(stage) - clutter_actor_get_height(foregroundImage)) / 2;
    } else {
        imageYposition = clutter_actor_get_height(stage) - (clutter_actor_get_height(stage) - clutter_actor_get_height(backgroundImage)) / 2;
    }

    /* Add background image to wall */
    clutter_actor_set_anchor_point(backgroundImage, 0, clutter_actor_get_height(backgroundImage));
    clutter_actor_set_position(backgroundImage, backgroundImageXposition, imageYposition);
    clutter_container_add_actor(CLUTTER_CONTAINER(wall), backgroundImage);

    /* Add foreground image to wall */
    clutter_actor_set_anchor_point(foregroundImage, 0, clutter_actor_get_height(foregroundImage));
    clutter_actor_set_position(foregroundImage, foregroundImageXposition, imageYposition);
    clutter_container_add_actor(CLUTTER_CONTAINER(wall), foregroundImage);
```

```
    /* Add wall to stage */
    clutter_actor_set_depth(wall, IMAGE_DEPTH);
    clutter_actor_set_rotation(wall, CLUTTER_Y_AXIS, WALL_ROTATION, 0, 0, 0);
    clutter_actor_set_anchor_point(wall, clutter_actor_get_width(wall) / 2, 0);
    clutter_actor_set_position(wall, clutter_actor_get_width(stage) / 2, 0);
    clutter_container_add_actor(CLUTTER_CONTAINER(stage), wall);
    clutter_actor_show(wall);

    /* Display stage */
    clutter_actor_show(stage);

    /* Time Line 3D Right Wall */
    clutter_main();

    /* Report image details */
    gfloat left = 0.0;
    gfloat top = 0.0;
    gfloat width = 0.0;
    gfloat height = 0.0;
    clutter_actor_get_transformed_position(backgroundImage, &left, &top);
    clutter_actor_get_transformed_size(backgroundImage, &width, &height);
    printf("\n");
    printf(" width = %3d\n", (int) (width + 0.5));
    printf("height = %3d\n", (int) (height + 0.5));
    printf("  left = %3d  ->  %3d\n", (int) (left + 0.5), (int) (left + 10.5));
    printf("   top = %3d  ->  %3d\n", (int) (top + 0.5), (int) (top + 100.5));
    clutter_actor_get_transformed_position(foregroundImage, &left, &top);
    clutter_actor_get_transformed_size(foregroundImage, &width, &height);
    printf("\n");
    printf(" width = %3d\n", (int) (width + 0.5));
    printf("height = %3d\n", (int) (height + 0.5));
    printf("  left = %3d  ->  %3d\n", (int) (left + 0.5), (int) (left + 10.5));
    printf("   top = %3d  ->  %3d\n", (int) (top + 0.5), (int) (top + 100.5));

    return EXIT_SUCCESS;
}
```

```
#!/bin/bash
#----------------------------------------------------------------------
#
#   mkImage         1.0             11/06/2012
#
#   Original:       Greg Clarke     11/06/2012
#
#   Modifications:
#
#
#   Objective:      Generate set of web survey images to upload to
#                   SurveyWriter.
#
#   Options:
#
#   Arguments:      [ all | tl | 3d | lw | rw ] <webSurveyQuestion>
#
#   Outputs:        Image files in JPG format.
#
#----------------------------------------------------------------------

#
# Default: Generate all temporal information visualisation types.
#
program="all"

#
# Remove existing images.
#
rmImage() {
    if [ -L backgroundImage.jpg ];
    then
        rm backgroundImage.jpg
    fi
    if [ -L foregroundImage.jpg ];
    then
        rm foregroundImage.jpg
    fi
    if [ -L leftImage.jpg ];
    then
        rm leftImage.jpg
    fi
    if [ -L rightImage.jpg ];
    then
        rm rightImage.jpg
    fi
    if [ -f backgroundImage.jpg ];
    then
        rm backgroundImage.jpg
    fi
    if [ -f foregroundImage.jpg ];
    then
        rm foregroundImage.jpg
    fi
    if [ -f leftImage.jpg ];
    then
        rm leftImage.jpg
    fi
    if [ -f rightImage.jpg ];
    then
        rm rightImage.jpg
    fi
}

#
# Display temporal information visualisation image.
#
displayImage() {
    case $1 in
        [tT][lL] )
            ./tl &
            ;;
        3[dD] | [tT][lL]3[dD] )
            ./tl3d &
            ;;
        [rR][wW] | [tT][lL]3[dD][rR][wW] )
            ./tl3drw &
            ;;
        [lL][wW] | [tT][lL]3[dD][lL][wW] )
            ./tl3dlw &
            ;;
        * )
            ./tl &
            sleep 1
            ./tl3d &
            sleep 1
            ./tl3dlw &
            sleep 1
            ./tl3drw &
```

```
            ;;
    esac
    sleep 1
}

#
# Evaluate temporal information visualisation type argument.
#
if [ $# -gt 1 ];
then
    program=$1
    shift
fi

#
# Evaluate source images.
#
if [ ! -d image/cooked/$1 ];
then
    echo "Image folder missing!"
    exit
fi
if [ ! -f image/cooked/$1/o.jpg ];
then
    echo "Source image file o.jpg is missing!"
    exit
fi
if [ ! -f image/cooked/$1/y.jpg ];
then
    echo "Source image file y.jpg is missing!"
    exit
fi
if [ "$program" != "all" ];
then
    if [ ! -f image/cooked/$1/h.jpg ];
    then
        echo "Source image file h.jpg is missing!"
        exit
    fi
fi

#
# Link source images as current image set
#
if [ $# -eq 2 ];
then
    rmImage
    ln -s image/cooked/$1/h.jpg backgroundImage.jpg
    ln -s image/cooked/$1/h.jpg foregroundImage.jpg
    ln -s image/cooked/$1/h.jpg leftImage.jpg
    ln -s image/cooked/$1/h.jpg rightImage.jpg
    displayImage $program
fi
rmImage
ln -s image/cooked/$1/o.jpg backgroundImage.jpg
ln -s image/cooked/$1/y.jpg foregroundImage.jpg
ln -s image/cooked/$1/o.jpg leftImage.jpg
ln -s image/cooked/$1/y.jpg rightImage.jpg
displayImage $program
```

Appendix D

Statistical Analysis Program Output


```
Temporal information visualisation survey questions.
----------------------------------------------------
11  Which is the younger horse?
12  Which perfume bottle is the older?
13  Which dress was designed first?
14  This is the shadow of a mountain cast at sunrise and sunset.  Which is the sunset shadow?
15  Which video game was released first?
21  Which is the older ship?
22  Which painting is the older?
23  Which of these two lunar landers was the last to land on the moon?
24  Which Greek amphora is the younger?
25  Which bronze was cast first?
31  Which is the most recent stamp issued?
32  Which is the older of these Faberge eggs?
33  Which is the current currency?
34  Which book was published first?
35  Which movie was made first?
41  Which of these two pieces of wearable art was created first?
42  Which of these two kings of England reigned first?
43  Which of these two is the last to open each day?
44  Which of these two hydroelectric dams was built first?
45  Which of the two dolls is the older?

Participant count : 107

Particpant temporal progression orientation matching expected orientation.
==========================================================================
11  Which is the younger horse?                                       :  42%
12  Which perfume bottle is the older?                                :  32%
13  Which dress was designed first?                                   :  52%
14  This is the shadow of a mountain cast at sunrise and sunset.  Wh  :  61%
15  Which video game was released first?                              :  59%

21  Which is the older ship?                                          :  80%
22  Which painting is the older?                                      :  62%
23  Which of these two lunar landers was the last to land on the moo  :  59%
24  Which Greek amphora is the younger?                               :  63%
25  Which bronze was cast first?                                      :  59%

31  Which is the most recent stamp issued?                            :  49%
32  Which is the older of these Faberge eggs?                         :  76%
33  Which is the current currency?                                    :  58%
34  Which book was published first?                                   :  61%
35  Which movie was made first?                                       :  47%

41  Which of these two pieces of wearable art was created first?      :  57%
42  Which of these two kings of England reigned first?                :  62%
43  Which of these two is the last to open each day?                  :  49%
44  Which of these two hydroelectric dams was built first?            :  61%
45  Which of the two dolls is the older?                              :  80%

Descriptive statistical analysis of particpant temporal progression orientation.
--------------------------------------------------------------------------------
Survey question average precentage of particpant temporal progression
orientation grouped by temporal information visualisation technique.
```

Question	Time Line	3D	3D Right Wall	3D Left Wall
1	42%	80%	49%	57%
2	32%	62%	76%	62%
3	52%	59%	58%	49%
4	61%	63%	61%	61%
5	59%	59%	47%	80%
Mean	49	64	58	62
Median	52	62	58	61
Variance	148	82	134	136
Std Dev	12	9	12	12

```
Horizontal and Spatial Temporal Information Visualisation Techniques
====================================================================
Participant temporal progression orientation percentage matching
expected outcome frequency distribution.
----------------------------------------------------------------
   0% :                         ( 0)
   5% :                         ( 0)
  10% :                         ( 0)
  15% :                         ( 0)
  20% :                         ( 0)
  25% :                         ( 0)
  30% : #                       ( 1)
  35% : ########                ( 8)
  40% : #######                 ( 7)
  45% : ############            (12)
  50% : #############           (13)
  55% : ##############          (14)
  60% : ################        (16)
  65% : ###########             (11)
  70% : ####                    ( 4)
  75% : ####                    ( 4)
  80% : ########                ( 8)
  85% : #####                   ( 5)
  90% : ##                      ( 2)
  95% : ##                      ( 2)
 100% :                         ( 0)
----------------------------------------------------------------
100% indicates temporal progression orientation matches expected outcome
for all questions, where as 0% indicates reversed temporal progression
orientation to expected outcome for all questions.
    Mean       Median     Variance     Std Dev      Lower       Upper       Range
     58          55         235          15           30          95          65


Time Line
=========
Participant horizontal left/right temporal progression orientation
percentage frequency distribution
----------------------------------------------------------------
   0% : ####                                    ( 4)
  20% : ###################                     (19)
  40% : ################################        (32)
  60% : ################################        (32)
  80% : ################                        (16)
 100% : ####                                    ( 4)
----------------------------------------------------------------
100% indicates a left to right temporal progression orientation for all
questions, 0% indicates a right to left orientation.
    Mean       Median     Variance     Std Dev
     49          40         546          23
Chi-Square: 0.723    P-Value: 0.982    d.f.: 5    N: 107


 3D
====
Participant spatial temporal progression orientation percentage
frequency distribution.
----------------------------------------------------------------
   0% : ##                              ( 2)
  20% : #########                       ( 9)
  40% : #######################         (23)
  60% : #########################       (25)
  80% : #########################       (25)
 100% : #######################         (23)
----------------------------------------------------------------
100% indicates a spatial temporal progression orientation where the
greater the depth the greater the age of the object, where as 0%
indicates a spatial temporal progression orientation where the object in
the foreground is the older.
    Mean       Median     Variance     Std Dev
     64          60         712          27
Chi-Square: 129.142    P-Value: 0.000    d.f.: 5    N: 107
```

surveyAnalysis.txt **Page 3 of 6**

```
3D Right Wall
=============
Participant spatial temporal progression orientation percentage
frequency distribution.
----------------------------------------------------------------
   0% : ##                                     ( 2)
  20% : ################                       (16)
  40% : ######################                 (22)
  60% : ################################       (32)
  80% : #####################                  (21)
 100% : ##############                         (14)
----------------------------------------------------------------
100% indicates a spatial temporal progression orientation where the
greater the depth the greater the age of the object, where as 0%
indicates a spatial temporal progression orientation where the object in
the foreground is the older.
    Mean       Median     Variance     Std Dev
     58          60         679          26
Chi-Square: 39.602    P-Value: 0.000    d.f.: 5    N: 107


3D Left Wall
============
Participant spatial temporal progression orientation percentage
frequency distribution.
----------------------------------------------------------------
   0% : ###                                    ( 3)
  20% : ########                               ( 8)
  40% : #####################                  (21)
  60% : ###################################    (35)
  80% : #########################              (25)
 100% : ###############                        (15)
----------------------------------------------------------------
100% indicates a spatial temporal progression orientation where the
greater the depth the greater the age of the object, where as 0%
indicates a spatial temporal progression orientation where the object in
the foreground is the older.
    Mean       Median     Variance     Std Dev
     62          60         620          25
Chi-Square: 54.017    P-Value: 0.000    d.f.: 5    N: 107


3D Wall Combined
================
Participant spatial temporal progression orientation percentage
frequency distribution.
----------------------------------------------------------------
   0% : ##                                             ( 2)
  20% : ###                                            ( 3)
  40% : ###################                            (19)
  60% : ############################################### (47)
  80% : ######################                         (22)
 100% : ##############                                 (14)
----------------------------------------------------------------
100% indicates a spatial temporal progression orientation where the
greater the depth the greater the age of the object, where as 0%
indicates a spatial temporal progression orientation where the object in
the foreground is the older.
    Mean       Median     Variance     Std Dev
     60          60         377          19


Spatial
=======
Participant spatial temporal progression orientation percentage
frequency distribution.
----------------------------------------------------------------
   0% :                                        ( 0)
  20% : ########                               ( 8)
  40% : ######################                 (22)
  60% : #################################      (33)
  80% : ###########################            (27)
 100% : #################                      (17)
----------------------------------------------------------------
100% indicates a spatial temporal progression orientation where the
greater the depth the greater the age of the object, where as 0%
indicates a spatial temporal progression orientation where the object in
the foreground is the older.
    Mean       Median     Variance     Std Dev
     61          60         340          18
```

```
Number of particpants with a spatial temporal progression orientation of
the past in the background in the 3D information visualisations : 23



100% Spatial 3D
===============
Participant spatial temporal progression orientation percentage
frequency distribution.
----------------------------------------------------------------
   0% :                        ( 0)
  20% :                        ( 0)
  40% :                        ( 0)
  60% :                        ( 0)
  80% :                        ( 0)
 100% : ####################### (23)
----------------------------------------------------------------
100% indicates a spatial temporal progression orientation where the
greater the depth the greater the age of the object, where as 0%
indicates a spatial temporal progression orientation where the object in
the foreground is the older.
    Mean       Median     Variance     Std Dev
    100         100          0           0


100% Spatial 3D - 3D Right Wall
===============================
Participant spatial temporal progression orientation percentage
frequency distribution.
----------------------------------------------------------------
   0% :                ( 0)
  20% : #              ( 1)
  40% : #              ( 1)
  60% : #####          ( 5)
  80% : ######         ( 6)
 100% : ##########     (10)
----------------------------------------------------------------
100% indicates a spatial temporal progression orientation where the
greater the depth the greater the age of the object, where as 0%
indicates a spatial temporal progression orientation where the object in
the foreground is the older.
    Mean       Median     Variance     Std Dev
     80          80         509          23


100% Spatial 3D - 3D Left Wall
==============================
Participant spatial temporal progression orientation percentage
frequency distribution.
----------------------------------------------------------------
   0% :                ( 0)
  20% : #              ( 1)
  40% : ##             ( 2)
  60% : #####          ( 5)
  80% : #######        ( 7)
 100% : ########       ( 8)
----------------------------------------------------------------
100% indicates a spatial temporal progression orientation where the
greater the depth the greater the age of the object, where as 0%
indicates a spatial temporal progression orientation where the object in
the foreground is the older.
    Mean       Median     Variance     Std Dev
     77          80         533          23


100% Spatial 3D - 3D Wall Combined
==================================
Participant spatial temporal progression orientation percentage
frequency distribution.
----------------------------------------------------------------
   0% :                ( 0)
  20% :                ( 0)
  40% : #              ( 1)
  60% : ####           ( 4)
  80% : #########      ( 9)
 100% : #########      ( 9)
----------------------------------------------------------------
100% indicates a spatial temporal progression orientation where the
greater the depth the greater the age of the object, where as 0%
indicates a spatial temporal progression orientation where the object in
the foreground is the older.
    Mean       Median     Variance     Std Dev
     78          80         315          18
```

```
100% Spatial 3D - Spatial
========================
Participant spatial temporal progression orientation percentage
frequency distribution.
---------------------------------------------------------------
   0% :                 ( 0)
  20% :                 ( 0)
  40% :                 ( 0)
  60% : #               ( 1)
  80% : ########        ( 8)
 100% : ##############  (14)
---------------------------------------------------------------
100% indicates a spatial temporal progression orientation where the
greater the depth the greater the age of the object, where as 0%
indicates a spatial temporal progression orientation where the object in
the foreground is the older.
    Mean       Median     Variance     Std Dev
     86          87         140          12



Number of particpants with a dominant spatial temporal progression
orientation of the past in the background in the 3D information
visualisations : 48



Dominant Spatial 3D
===================
Participant spatial temporal progression orientation percentage
frequency distribution.
---------------------------------------------------------------
   0% :                                 ( 0)
  20% :                                 ( 0)
  40% :                                 ( 0)
  60% :                                 ( 0)
  80% : #########################       (25)
 100% : #######################         (23)
---------------------------------------------------------------
100% indicates a spatial temporal progression orientation where the
greater the depth the greater the age of the object, where as 0%
indicates a spatial temporal progression orientation where the object in
the foreground is the older.
    Mean       Median     Variance     Std Dev
     90          80         102          10


Dominant Spatial 3D - 3D Right Wall
===================================
Participant spatial temporal progression orientation percentage
frequency distribution.
---------------------------------------------------------------
   0% :                 ( 0)
  20% : ####            ( 4)
  40% : #########       ( 9)
  60% : ############### (15)
  80% : ########        ( 8)
 100% : ############    (12)
---------------------------------------------------------------
100% indicates a spatial temporal progression orientation where the
greater the depth the greater the age of the object, where as 0%
indicates a spatial temporal progression orientation where the object in
the foreground is the older.
    Mean       Median     Variance     Std Dev
     66          60         649          25


Dominant Spatial 3D - 3D Left Wall
==================================
Participant spatial temporal progression orientation percentage
frequency distribution.
---------------------------------------------------------------
   0% : #               ( 1)
  20% : #               ( 1)
  40% : ##########      (10)
  60% : ###########     (11)
  80% : ##############  (14)
 100% : ###########     (11)
---------------------------------------------------------------
100% indicates a spatial temporal progression orientation where the
greater the depth the greater the age of the object, where as 0%
indicates a spatial temporal progression orientation where the object in
the foreground is the older.
    Mean       Median     Variance     Std Dev
     69          80         611          25
```

```
Dominant Spatial 3D - 3D Wall Combined
=====================================
Participant spatial temporal progression orientation percentage
frequency distribution.
---------------------------------------------------------------
   0% : #                      ( 1)
  20% :                        ( 0)
  40% : #####                  ( 5)
  60% : #################      (17)
  80% : ##############         (14)
 100% : ###########            (11)
---------------------------------------------------------------
100% indicates a spatial temporal progression orientation where the
greater the depth the greater the age of the object, where as 0%
indicates a spatial temporal progression orientation where the object in
the foreground is the older.
    Mean       Median     Variance     Std Dev
     68          70         415          20

Dominant Spatial 3D - Spatial
=============================
Participant spatial temporal progression orientation percentage
frequency distribution.
---------------------------------------------------------------
   0% :                        ( 0)
  20% : #                      ( 1)
  40% :                        ( 0)
  60% : ##########             (10)
  80% : #####################  (21)
 100% : ################       (16)
---------------------------------------------------------------
100% indicates a spatial temporal progression orientation where the
greater the depth the greater the age of the object, where as 0%
indicates a spatial temporal progression orientation where the object in
the foreground is the older.
    Mean       Median     Variance     Std Dev
     75          73         243          16
```

Appendix E

Statistical Analysis Program

The Perl modules, Chart::Clicker, Math::NumberCruncher, Statistics::Descriptive, Statistics::Distribution, and Statistics::Frequency, are not included in a regular Perl install. The modules can be obtained and built from the Perl repositories. Note: Chart::Clicker and its dependencies will take 30 minutes to build.

```
#!/usr/bin/perl -w
use strict;
#----------------------------------------------------------------------
#
#   surveyAnalysis  1.0             02/09/2012
#
#   Original:       Greg Clarke     02/09/2012
#
#   Modifications:
#
#
#   Objective:      Perform statistical analysis of survey data.
#
#   Options:        -d      Debug
#                   -h      Help
#                   -n      Normalise bar graph.
#
#   Arguments:      <csvDataFile>
#
#   Outputs:        Statistical analysis in text format.
#                   Graph image files in PNG format.
#
#----------------------------------------------------------------------

#
# Modules
#
use Chart::Clicker;
use Chart::Clicker::Renderer::Bar;
use Const::Fast;
use Getopt::Std;
use File::Basename;
use Math::NumberCruncher;
use Statistics::Descriptive;
use Statistics::Distributions;
use Statistics::Frequency;
use Text::Format;

#
# Constants
#
const my $USAGE_MESSAGE => 'Usage: ' . basename($0) . " [options] <csv_data_file>\n  -d\tDebug\n  -h\tHelp\n  -n\tNormalise bar graph\n\n";
const my @DEBUG_STRING_INSERT => ('horizontal left/right',
                                  'spatial depth for time',
                                  'spatial right wall depth for time',
                                  'spatial left wall depth for time', 'to expected outcome');
const my @EXPECTED_OUTCOME_TIME_LINE_VISUALISATION_TECHNIQUE => (2, 1, 1, 2, 1);
const my @EXPECTED_OUTCOME_3D_VISUALISATION_TECHNIQUE => (1, 1, 2, 2, 1);
const my @EXPECTED_OUTCOME_3D_RIGHT_WALL_VISUALISATION_TECHNIQUE => (2, 1, 2, 1, 1);
const my @EXPECTED_OUTCOME_3D_LEFT_WALL_VISUALISATION_TECHNIQUE => (1, 1, 2, 1, 1);
const my @EXPECTED_OUTCOME => (\@EXPECTED_OUTCOME_TIME_LINE_VISUALISATION_TECHNIQUE,
                               \@EXPECTED_OUTCOME_3D_VISUALISATION_TECHNIQUE,
                               \@EXPECTED_OUTCOME_3D_RIGHT_WALL_VISUALISATION_TECHNIQUE,
```

```
                                 \@EXPECTED_OUTCOME_3D_LEFT_WALL_VISUALISATION_TECHNIQUE);
const my @VISUALISATION_TECHNIQUE => ('Time Line', '3D', '3D Right Wall', '3D Left Wall');
const my %VISUALISATION_TECHNIQUE => ($VISUALISATION_TECHNIQUE[0] => 0,
                                        $VISUALISATION_TECHNIQUE[1] => 1,
                                        $VISUALISATION_TECHNIQUE[2] => 2,
                                        $VISUALISATION_TECHNIQUE[3] => 3);

#
# Variables
#
my($binomialDistributionFrequency) = 0;
my($column) = 0;
my($columnUnderline) = 0;
my($data) = 0;
my($line) = 0;
my($options) = 0;
my($participant) = 0;
my($participantLeftRightOrientationPercentageFrequency) = 0;
my($participantResponseVsExpectedOutcomePercentage) = 0;
my($participantResponseVsExpectedOutcomePercentageFrequency) = 0;
my($participantSpatialOrientationPercentageFrequency) = 0;
my($question) = 0;
my($rightLeftOrientatedParticipantCountTotal) = 0;
my($row) = 0;
my($threeDQuestionStat) = 0;
my($threeDLeftWallQuestionStat) = 0;
my($threeDRightWallQuestionStat) = 0;
my($timeLineQuestionStat) = 0;
my(@binomialDistribution);
my(@binomialDistributionFrequency);
my(@data);
my(@expectedOutcomePercentage);
my(@participant);
my(@participantData);
my(@participantLeftRightOrientationPercentage);
my(@participantLeftRightOrientationPercentageFrequency);
my(@participantResponseVsExpectedOutcomePercentage);
my(@participantSpatialOrientationPercentage);
my(@participantSpatialOrientationPercentageFrequency);
my(@question);
my(@questionID);
my(@rightLeftOrientatedParticipant);
my(@spatialOrientatedParticipant);
my(%binomialDistributionFrequency);
my(%chiSquare);
my(%graphDetail);
my(%option);
my(%participantLeftRightOrientationPercentageFrequency);
my(%participantResponseVsExpectedOutcomePercentage);
my(%participantResponseVsExpectedOutcomePercentageFrequency);
my(%participantSpatialOrientationPercentageFrequency);

    #
```

```
    # Array index to expected outcome array field.
    #
    sub arrayIndexToExpectedOutcomeArrayField {
        my($index) = $_[0];
        my(@expectedOutcome) = @{$_[1]};
        my($expectedOutcomeCount) = 0;
        for (my($record) = 0; $record < scalar(@expectedOutcome); $record++) {
            for (my($field) = 0; $field < scalar(@{$expectedOutcome[$record]}); $field++) {
                return($field) if ($index == $expectedOutcomeCount);
                $expectedOutcomeCount++;
            }
        }
        return(-1);
    }

    #
    # Array index to expected outcome array record.
    #
    sub arrayIndexToExpectedOutcomeArrayRecord {
        my($index) = $_[0];
        my(@expectedOutcome) = @{$_[1]};
        my($expectedOutcomeCount) = 0;
        for (my($record) = 0; $record < scalar(@expectedOutcome); $record++) {
            for (my($field) = 0; $field < scalar(@{$expectedOutcome[$record]}); $field++) {
                return($record) if ($index == $expectedOutcomeCount);
                $expectedOutcomeCount++;
            }
        }
        return(-1);
    }

    #
    # Basic statistical analysis.
    #
    sub basicStatisticalAnalysisReport {
        my(@data) = @_;
        my(@statisticalAnalysis);
        my($statistics) = Statistics::Descriptive::Full->new();
        $statistics->add_data(@data);
        $statistics->sort_data();
        $statistics->presorted(1);
        # Column headers.
        push(@statisticalAnalysis, "    Mean       Median     Variance     Std Dev\n");
        # Values
        push(@statisticalAnalysis, sprintf("%7.0f%12.0f%12.0f%12.0f\n", $statistics->mean(), $statistics->median(), $statistics->variance(), $statistics->standard_dev
iation()));
        return(@statisticalAnalysis);
    }

    #
    # Basic statistical analysis with bounds.
    #
    sub basicStatisticalAnalysisWithBoundsReport {
```

```
    my(@data) = @_;
    my(@statisticalAnalysisWithBounds) = &basicStatisticalAnalysisReport(@data);
    chomp(@statisticalAnalysisWithBounds);
    my($statistics) = Statistics::Descriptive::Full->new();
    $statistics->add_data(@data);
    $statistics->sort_data();
    $statistics->presorted(1);
    # Column headers.
    $statisticalAnalysisWithBounds[0] .= "      Lower       Upper       Range\n";
    # Values
    $statisticalAnalysisWithBounds[1] .= sprintf("%12.0f%12.0f%12.0f\n", $statistics->min(), $statistics->max(), $statistics->sample_range());
    return(@statisticalAnalysisWithBounds);
}

#
# Binomial distribution.
#
sub binomial {
    my($trials) = $_[0];
    my($successes) = $_[1];
    my($probability) = $_[2];
    while ($probability > 1) {
        $probability /= 100;
    }
    return($successes == 0) if ($probability == 0);
    return($successes != $trials) if ($probability == 1);
    return(Math::NumberCruncher::Choose($trials, $successes) * $probability ** $successes * (1 - $probability) ** ($trials - $successes));
}

#
# Generate Binomial frequency distribution.
#
sub binomialDistribution {
    my($population) = $_[0];
    my($trials) = $_[1];
    my($probability) = $_[2];
    while ($probability > 1) {
        $probability /= 100;
    }
    my(@binomialDistribution);
    for (my($successes) = 0; $successes <= $trials; $successes++) {
        $binomialDistribution[$successes] = &binomial($trials, $successes, $probability) * $population;
    }
    return(@binomialDistribution);
}

#
# Chi-Square.
#
sub chiSquare {
    my(@observed) = @{$_[0]};
    my(@expected) = @{$_[1]};
    return(-1) if ((scalar(@observed) != scalar(@expected)) || (scalar(@observed) < 2) || (scalar(@expected) < 2));
```

```
        my(%chiSquare);
        $chiSquare{df} = scalar(@observed) - 1;
        $chiSquare{statistic} = 0;
        for (my($i) = 0; $i < scalar(@observed); $i++) {
            $chiSquare{statistic} += ($observed[$i] - $expected[$i]) ** 2 / $expected[$i];
        }
        $chiSquare{p_value} = Statistics::Distributions::chisqrprob($chiSquare{df}, $chiSquare{statistic});
        return(%chiSquare);
    }

    #
    # Chi-Square report.
    #
    sub chiSquareReport {
        my(@observed) = @{$_[0]};
        my(@expected) = @{$_[1]};
        return(-1) if ((scalar(@observed) != scalar(@expected)) || (scalar(@observed) < 2) || (scalar(@expected) < 2));
        my(%chiSquare) = &chiSquare(\@observed, \@expected);
        return(sprintf("Chi-Square: %.3f    P-Value: %.3f    d.f.: %s    N: %s\n", $chiSquare{statistic}, $chiSquare{p_value}, $chiSquare{df}, scalar(@participantData
)));
        return(sprintf("Chi-Square : %9.6f    P-Value : %4.3f    d.f. : %d    N : %3d\n", $chiSquare{statistic}, $chiSquare{p_value}, $chiSquare{df}, scalar(@particip
antData)));
    }

    #
    # Consolidate percent hash keys into new percentage groups.
    #
    sub consolidatePercentHashKeys {
        my(%oldHash) = %{$_[0]};
        my($intervalGroups) = $_[1];
        my(%newHash);
        $newHash{0} = 0;
        for (my($i) = 1; $i < $intervalGroups; $i++) {
            $newHash{$i * 100 / ($intervalGroups - 1)} = 0;
        }
        my($key);
        foreach $key (keys(%oldHash)) {
            $newHash{int(($key - abs($key == 100)) / (100 / $intervalGroups)) * 100 / ($intervalGroups - 1)} += $oldHash{$key};
        }
        return(%newHash);
    }

    #
    # Convert hash keys from float to int
    #
    sub convertHashKeysFloatToInt {
        my(%floatKeyHash) = %{$_[0]};
        my($key, %intKeyHash);
        foreach $key (keys %floatKeyHash) {
            $intKeyHash{sprintf("%3.0f", $key)} += $floatKeyHash{$key};
        }
        return(%intKeyHash);
    }
```

```
#
# Debug string insert index.
#
sub debugStringInsertIndex {
    my(@visualisationTechnique) = @{$_[0]};
    return($visualisationTechnique[0]) if (scalar(@visualisationTechnique) == 1);
    return(4) if (scalar(@visualisationTechnique) == 4);
    return(1);
}

#
# Count of expected outcomes for record (N..M)
#
sub expectedOutcomeCount {
    my(@record) = @{$_[0]};
    my(@expectedOutcome) = @{$_[1]};
    my($expectedOutcomeCount) = 0;
    my($record);
    foreach $record (@record) {
        $expectedOutcomeCount += scalar(@{$expectedOutcome[$record]});
    }
    return($expectedOutcomeCount);
}

#
# Frequency graph.
#
sub frequencyGraph {
    my(%graphData) = %{$_[0]};
    my($maxFrequency) = &max(values(%graphData));
    my(@frequencyGraph);
    my($graphWidth) = (int($maxFrequency / 8) + 1) * 8;
    my($boarder) = sprintf("%s\n", '-' x (64 * abs($graphWidth <= 48) + ($graphWidth + 16) * abs($graphWidth > 48)));
    push(@frequencyGraph, $boarder);
    my($key);
    foreach $key (sort({$a <=> $b} keys(%graphData))) {
        push(@frequencyGraph, sprintf("%4.0f%% : %-${graphWidth}s(%2d)\n", $key, '#' x $graphData{$key}, $graphData{$key}));
    }
    push(@frequencyGraph, $boarder);
    return(@frequencyGraph);
}

#
# Frequency hash to frequency array.
#
sub frequencyHashToFrequencyArray {
    my(%frequencyHash) = %{$_[0]};
    my($key, @frequencyArray);
    foreach $key (sort({$a <=> $b} keys(%frequencyHash))) {
        push(@frequencyArray, $frequencyHash{$key});
    }
    return(@frequencyArray);
```

```
}

#
# Graph.
#
sub graph {
    #
    # Define default components.
    #
    my($title) = "GRAPH";
    my(@domainAxisTickLabel) = qw(Background > | < Foreground);
    my(@domainAxisTickValue) = qw(0 25 50 75 100);
    my($graphRangeMax) = 10;
    my($label) = 'Temporal progressions orientation. Past in the background to the past in the foreground.';
    my(@legend) = ('Participant responses.',
                   'Binomial distribution representing random responses.');
    my($filename) = 'graph.png';
    my($orientate) = 1;
    #
    # Evaluate arguments and extract data.
    #
    # Graph data.
    my(@graphData) = @{$_[0]};
    if ($#_ > 0) {
        # Graph arguments.
        my(%graphArgument) = %{$_[1]};
        my($key);
        foreach $key (keys (%graphArgument)) {
            if ($key eq 'title') {
                $title = $graphArgument{'title'};
            } elsif ($key eq 'axisTickLabels') {
                @domainAxisTickLabel = split(/\s+/, $graphArgument{'axisTickLabels'});
            } elsif ($key eq 'axisLeftTickLabel') {
                $domainAxisTickLabel[0] = $graphArgument{'axisLeftTickLabel'};
            } elsif ($key eq 'axisRightTickLabel') {
                $domainAxisTickLabel[$#domainAxisTickLabel] = $graphArgument{'axisRightTickLabel'};
            } elsif ($key eq 'axisTickValues') {
                @domainAxisTickValue = split(/\s+/, $graphArgument{'axisTickValues'});
            } elsif ($key eq 'label') {
                $label = $graphArgument{'label'};
            } elsif ($key eq 'rangeMax') {
                $graphRangeMax = $graphArgument{'rangeMax'};
            } elsif ($key eq 'filename') {
                $filename = $graphArgument{'filename'};
            } elsif ($key eq 'orientate') {
                $orientate = $graphArgument{'orientate'}
            }
        }
        # Data series legends.
        if ($#_ > 1) {
            @legend = @{$_[2]};
        }
        # Ensure label and value array lengths match.
```

```
        if ($#domainAxisTickLabel != $#domainAxisTickValue) {
            if ($#domainAxisTickLabel < $#domainAxisTickValue) {
                do {
                    push(@domainAxisTickLabel, ' ');
                } until ($#domainAxisTickLabel == $#domainAxisTickValue);
            } else {
                do {
                    pop(@domainAxisTickLabel);
                } until ($#domainAxisTickLabel == $#domainAxisTickValue);
            }
        }
    }
    #
    # Compile graph data.
    #
    my(@series);
    for (my($graphData) = 0; $graphData < scalar(@graphData); $graphData++) {
        my($key, @key, @value);
        foreach $key (sort({$a <=> $b} (keys %{$graphData[$graphData]}))) {
            push(@key, $key);
            push(@value, ${$graphData[$graphData]}{$key});
        }
        @value = reverse(@value) if ($orientate);
        $series[$graphData] = Chart::Clicker::Data::Series->new(keys => \@key, values => \@value);
    }
    my($dataSet) = Chart::Clicker::Data::DataSet->new(series => \@series);
    #
    # Construct graph.
    #
    # Calculate graph bounds.
    for (my($graphData) = 0; $graphData < scalar(@graphData); $graphData++) {
        $graphRangeMax = (int(&max(values(%{$graphData[$graphData]}))) / 10) + 1) * 10 if (((int(&max(values(%{$graphData[$graphData]}))) / 10) + 1) * 10) > $graphR
angeMax);
    }
    # Calculate graph range tick interval.
    my(@rangeTickInterval) = qw(1 2 5 10 20 25 50 100);
    my($rangeTickInterval) = $rangeTickInterval[0];
    for (my($i) = 1; ($i < scalar(@rangeTickInterval)) && (($graphRangeMax / $rangeTickInterval) > 10); $i++) {
        $rangeTickInterval = $rangeTickInterval[$i];
    }
    # Create graph object.
    my($graph) = Chart::Clicker->new({width => 1280, height => 960, padding => 31, format => 'png'});
    # Initialise colour pallet.
    $graph->color_allocator(Chart::Clicker::Drawing::ColorAllocator->new({seed_hue => 180}));
    # Remove border
    $graph->border->width(0);
    # Title
    $graph->title->text($title);
    $graph->title->font->size(28);
    $graph->title->font->weight('bold');
    $graph->title->padding->bottom(24);
    # Data
    $graph->add_to_datasets($dataSet);
```

```
        # Bar Graph
        my($barGraph) = Chart::Clicker::Renderer::Bar->new({bar_padding => 8, opacity => 0.64});
        # Amend graph render.
        $barGraph->brush->line_join('round');
        $barGraph->brush->width(15);
        # Get the default context for the graph.
        my($context) = $graph->get_context('default');
        # Amend context.
        $context->renderer($barGraph);
        $context->domain_axis->brush->width(2);
        $context->domain_axis->fudge_amount(.1);
        $context->domain_axis->label($label);
        $context->domain_axis->label_font->size(24);
        $context->domain_axis->tick_font->size(24);
        $context->domain_axis->tick_values([@domainAxisTickValue]);
        $context->domain_axis->tick_labels([@domainAxisTickLabel]);
        $context->domain_axis->tick_label_angle(6.28);
        $context->range_axis->label('Participants');
        $context->range_axis->label_font->size(26);
        $context->range_axis->brush->width(2);
        $context->range_axis->format("%d");
        $context->range_axis->range->min(0);
        $context->range_axis->range->max($graphRangeMax);
        $context->range_axis->ticks($graphRangeMax / $rangeTickInterval);
        $context->range_axis->tick_font->size(24);
        # Legend.
        if (scalar(@graphData) > 1) {
            $graph->legend->border->width(2);
            $graph->legend->font->size(24);
            $graph->legend->item_padding->top(8);
            $graph->legend->item_padding->bottom(8);
            $graph->legend->item_padding->left(8);
            $graph->legend->item_padding->right(64);
            for (my($legend) = 0; $legend < scalar(@legend); $legend++) {
                $series[$legend]->name(chr(0x2588) . ' ' . $legend[$legend]);
            }
        } else {
            # Remove legend if only a single series graphed.
            $graph->legend->border->width(0);
            $series[0]->name('');
        }
        # Write graph to file.
        $graph->write_output($filename);
    }

    #
    # Graph range maximum.
    #
    sub graphRangeMax {
        return(int($_[0] / 20) * 10 || 10);
    }

    #
```

```
    # Initialise frequency data.
    #
    sub initialiseFrequencyData {
        my(%frequencyData);
        if (! ref($_[0])) {
            my($dataSpread) = $_[0];
            $frequencyData{0} = 0;
            for (my($i) = 1; $i <= $dataSpread; $i++) {
                $frequencyData{$i * 100 / $dataSpread} = 0;
            }
        } else {
            my(@data) = @{$_[0]};
            $frequencyData{0} = $data[0];
            for (my($i) = 1; $i < scalar(@data); $i++) {
                $frequencyData{$i * 100 / $#data} = $data[$i];
            }
        }
        return(%frequencyData);
    }

    #
    # Max
    #
    sub max {
        my($max, @value) = @_;
        my($value);
        foreach $value (@value) {
            $max = $value if ($value > $max);
        }
        return($max);
    }

    #
    # Get participant list with temporal progression orientation percentages for analysis.
    #
    sub participant {
        my(@participant) = @{$_[0]};
        my(@participantData) = @{$_[1]};
        my(@visualisationTechnique) = @{$_[2]};
        my(@participantResponsePercentageScopeBound) = @{$_[3]};
        my(@expectedOutcome) = @{$_[4]};
        my($participant, @selectedParticipant);
        my(@participantResponseVsExpectedOutcomePercentage) = &participantResponseVsExpectedOutcomePercentage(\@participant, \@participantData, \@visualisationTechniq
ue, \@expectedOutcome);
        foreach $participant (@participant) {
            push(@selectedParticipant, $participant) if (($participantResponseVsExpectedOutcomePercentage[$participant] >= $participantResponsePercentageScopeBound[0]
) && ($participantResponseVsExpectedOutcomePercentage[$participant] <= $participantResponsePercentageScopeBound[$#participantResponsePercentageScopeBound]));
        }
        ($option{d}) && do {
            foreach $participant (@selectedParticipant) {
                printf("Participant %3d response matching expected outcome percentage %3d%% falls within the scope %3d%%", $participant + 1, $participantResponseVsExp
ectedOutcomePercentage[$participant], $participantResponsePercentageScopeBound[0]);
                printf(" - %3d%%", $participantResponsePercentageScopeBound[$#participantResponsePercentageScopeBound]) if ($#participantResponsePercentageScopeBound)
```

```
;
                print("\n");
            }
            print("\n");
        };
        return(@selectedParticipant);
    }

    #
    # Participant temporal progression orientation verses expected outcome percentages.
    #
    sub participantResponseVsExpectedOutcomePercentage {
        my(@participant) = @{$_[0]};
        my(@participantData) = @{$_[1]};
        my(@visualisationTechnique) = @{$_[2]};
        my(@expectedOutcome) = @{$_[3]};
        my($participant, @participantResponseVsExpectedOutcomePercentage, $visualisationTechnique);
        foreach $participant (@participant) {
            my($responseCount) = 0;
            my($participantResponseMatchesExpectedOutcomeCount) = 0;
            foreach $visualisationTechnique (@visualisationTechnique) {
                for (my($response) = 0; ($participant < scalar(@participantData)) && ($response < scalar(@{$participantData[$participant][$visualisationTechnique]}))
&& ($response < scalar(@{$expectedOutcome[$visualisationTechnique]})); $response++) {
                    $participantResponseMatchesExpectedOutcomeCount++ if ($participantData[$participant][$visualisationTechnique][$response] == $expectedOutcome[$visu
alisationTechnique][$response]);
                    $responseCount++;
                }
            }
            push(@participantResponseVsExpectedOutcomePercentage, $participantResponseMatchesExpectedOutcomeCount * 100 / $responseCount);
            ($option{d}) && printf("Participant %3d is oriented %s to a degree of %3.0f%%\n", $participant + 1, $DEBUG_STRING_INSERT[&debugStringInsertIndex(\@visuali
sationTechnique)], $participantResponseVsExpectedOutcomePercentage[$#participantResponseVsExpectedOutcomePercentage]);    # DEBUG
        }
        ($option{d}) && print("\n");
        return(@participantResponseVsExpectedOutcomePercentage);
    }

    #
    # Convert string to a two dimensional array with records and fields structured to match the expected outcome array.
    #
    sub stringToExpectedOutcomeMatrixArray {
        my(@expectedOutcome) = @{$_[1]};
        my($records) = scalar(@expectedOutcome);
        my($separator) = ',';
        $separator = $_[2] if ($#_ > 1);
        my(@data) = split(/$separator/, $_[0]);
        my(@array);
        for (my($record) = 0; $record < $records; $record++) {
            my($fields) = scalar(@{$expectedOutcome[$record]});
            for (my($field) = 0; $field < $fields; $field++) {
                if (($record * $fields + $field) < scalar(@data)) {
                    $array[$record][$field] = $data[$record * $fields + $field];
                }
            }
```

```
        }
        return(@array);
    }

    #
    # Display tombstone message and die.
    #
    sub tombstone {
        die("ERROR: @_\n");
    }

    #
    # Convert a two dimensional array to a string.
    #
    sub twoDimensionalArrayToString {
        my(@data) = @{$_[0]};
        my($separator) = ',';
        $separator = $_[1] if ($#_ > 0);
        my(@consolidatedArray);
        for (my($record) = 0; $record < scalar(@data); $record++) {
            push(@consolidatedArray, join($separator, @{$data[$record]}));
        }
        return(join($separator, @consolidatedArray));
    }

    #
    # Underline line.
    #
    sub underline {
        my($line) = $_[0];
        my($underline) = substr($_[1], 0, 1);
        return(sprintf("%s\n%s\n", $line, $underline x length($line)));
    }

    #
    # Display usage message.
    #
    sub usage {
        print($USAGE_MESSAGE);
        exit 0;
    }

    #
    # Wrap text.
    #
    sub wrapText {
        my($text) = Text::Format->new({ firstIndent => 0 });
        return($text->format(@_));
    }

#-----------------------------------------------------------------------
# Evaluate options and arguments.
#-----------------------------------------------------------------------
```

```
#
# Evaluate options.
#
$options = 'dhn';
getopts( "$options", \%option ) || &usage();
&usage() if $option{h};

#
# Evaluate arguments.
#
&tombstone("A comma separated data file is required.\n" . $USAGE_MESSAGE) if (@ARGV != 1);
&tombstone("$ARGV[0] does not exist.") unless (-e $ARGV[0]);
&tombstone("$ARGV[0] can not be accessed.") unless (-f $ARGV[0]);

#======================================================================
# Process survey data.
#======================================================================

#
# Get data column headers.
#
$line = <>;
@data = split(/\,/, $line, 21);
delete($data[$#data]);
foreach $data (@data) {
    $data =~ s/\"//g;
    $data =~ s/\s+$//;
    my(@questionData) = split(/_\s+/, $data);
    push(@questionID, $questionData[0]);
    push(@question, $questionData[1]);
}
#
# Display question ID and question text.
#
print("\n" . &underline('Temporal information visualisation survey questions.', '-'));
for (my($i) = 0; ($i < scalar(@questionID)) && ($i < scalar(@question)); $i++) {
    printf("%2d  %-32s\n", $questionID[$i], $question[$i]);
}
#
# Get participant data.
#
$participant = 0;
while (<>) {
    my(@data) = &stringToExpectedOutcomeMatrixArray($_, \@EXPECTED_OUTCOME);
    $participantData[$participant] = \@data;
    $participant++;
}
#
# Total number of participants.
#
print("\n\nParticipant count : " . scalar(@participantData) . "\n\n\n");
#
```

```
# Participant list.
#
@participant = (0..$#participantData);
#
# DEBUG - Response matrix
#
($option{d}) && do {
    for (my($participant) = 0; $participant < scalar(@participantData); $participant++) {
        printf("Participant %3d : ", $participant);
        print(&twoDimensionalArrayToString(\@{$participantData[$participant]}, ' ') . "\n");
    }
    print("\n");
};

#----------------------------------------------------------------------
# Participant temporal progression orientation analysis.
#----------------------------------------------------------------------
print(&underline('Particpant temporal progression orientation matching expected orientation.', '='));
for (my($question) = 0; ($question < scalar(@questionID)) && ($question < scalar(@question)); $question++) {
    my(%response);
    my($responses) = 0;
    my($record) = &arrayIndexToExpectedOutcomeArrayRecord($question, \@EXPECTED_OUTCOME);
    my($field) = &arrayIndexToExpectedOutcomeArrayField($question, \@EXPECTED_OUTCOME);
    for (my($participant) = 0; $participant < scalar(@participantData); $participant++) {
        if (($record < scalar(@{$participantData[$participant]})) && ($field < scalar(@{$participantData[$participant][$record]}))) {
            $response{$participantData[$participant][$record][$field]}++;
        }
        $responses++;
    }
    push(@expectedOutcomePercentage, $response{$EXPECTED_OUTCOME[$record][$field]} * 100 / $responses);
    printf("%2d  %-64s  : %3.0f%%\n", $questionID[$question], substr($question[$question], 0, 64), $expectedOutcomePercentage[$#expectedOutcomePercentage]);
    print("\n") if ($field == $#{$EXPECTED_OUTCOME[$record]});
    my($response);
    foreach $response (keys %response) {
        $response{$response} = 0;
    }
}
print("\n");
#
# Percentage Table
#
print(&underline('Descriptive statistical analysis of particpant temporal progression orientation.', '-'));
print(&wrapText('Survey question average precentage of particpant temporal progression orientation grouped by temporal information visualisation technique.') . "\n");
printf("%8s %12s %11s %21s %14s\n", 'Question', $VISUALISATION_TECHNIQUE[0], $VISUALISATION_TECHNIQUE[1], $VISUALISATION_TECHNIQUE[2], $VISUALISATION_TECHNIQUE[3]);
$columnUnderline = sprintf("%8s %15s %15s %15s %15s\n", '-' x 8, '=' x 15, '=' x 15, '=' x 15, '=' x 15);
print($columnUnderline);
$question = 1;
for ($row = 0; ($row * 4 + 3) < scalar(@expectedOutcomePercentage); $row++) {
    printf("%5d\t", $question);
    for ($column = 0; ($column < 4) && (($row * 4 + $column) < scalar(@expectedOutcomePercentage)); $column++) {
        printf("%9.0f%%\t", $expectedOutcomePercentage[$row + $column * 5]);
    }
    print("\n");
```

```
    $question++;
}
print("$columnUnderline");
#
# Question Statistics
#
$timeLineQuestionStat = Statistics::Descriptive::Full->new();
$timeLineQuestionStat->add_data(@expectedOutcomePercentage[0..4]);
$timeLineQuestionStat->sort_data();
$timeLineQuestionStat->presorted(1);
$threeDQuestionStat = Statistics::Descriptive::Full->new();
$threeDQuestionStat->add_data(@expectedOutcomePercentage[5..9]);
$threeDQuestionStat->sort_data();
$threeDQuestionStat->presorted(1);
$threeDRightWallQuestionStat = Statistics::Descriptive::Full->new();
$threeDRightWallQuestionStat->add_data(@expectedOutcomePercentage[10..14]);
$threeDRightWallQuestionStat->sort_data();
$threeDRightWallQuestionStat->presorted(1);
$threeDLeftWallQuestionStat = Statistics::Descriptive::Full->new();
$threeDLeftWallQuestionStat->add_data(@expectedOutcomePercentage[15..19]);
$threeDLeftWallQuestionStat->sort_data();
$threeDLeftWallQuestionStat->presorted(1);
# Mean
printf("Mean\t%9.0f\t%9.0f\t%9.0f\t%9.0f\n", $timeLineQuestionStat->mean(), $threeDQuestionStat->mean(), $threeDRightWallQuestionStat->mean(), $threeDLeftWallQuestion
Stat->mean());
# Median
printf("Median\t%9.0f\t%9.0f\t%9.0f\t%9.0f\n", $timeLineQuestionStat->median(), $threeDQuestionStat->median(), $threeDRightWallQuestionStat->median(), $threeDLeftWall
QuestionStat->median());
# Variance
printf("Variance%9.0f\t%9.0f\t%9.0f\t%9.0f\n", $timeLineQuestionStat->variance(), $threeDQuestionStat->variance(), $threeDRightWallQuestionStat->variance(), $threeDLe
ftWallQuestionStat->variance());
# Standard Deviation
printf("Std Dev\t%9.0f\t%9.0f\t%9.0f\t%9.0f\n\n\n", $timeLineQuestionStat->standard_deviation(), $threeDQuestionStat->standard_deviation(), $threeDRightWallQuestionSt
at->standard_deviation(), $threeDLeftWallQuestionStat->standard_deviation());

#-----------------------------------------------------------------------
# Frequency distribution of participant temporal progression orientation.
#-----------------------------------------------------------------------
#
@participantResponseVsExpectedOutcomePercentage = &participantResponseVsExpectedOutcomePercentage(\@participant, \@participantData, [values(%VISUALISATION_TECHNIQUE)]
, \@EXPECTED_OUTCOME);
#
# Calculate participant temporal progression orientation percentage frequency distribution.
#
%participantResponseVsExpectedOutcomePercentageFrequency = &initialiseFrequencyData(&expectedOutcomeCount([values(%VISUALISATION_TECHNIQUE)], \@EXPECTED_OUTCOME));
$participantResponseVsExpectedOutcomePercentageFrequency = Statistics::Frequency->new(\%participantResponseVsExpectedOutcomePercentageFrequency);
$participantResponseVsExpectedOutcomePercentageFrequency->add_data(@participantResponseVsExpectedOutcomePercentage);
%participantResponseVsExpectedOutcomePercentageFrequency = $participantResponseVsExpectedOutcomePercentageFrequency->frequencies;
#
# Display participant temporal progression orientation percentage frequency distribution graph and statistics.
#
print(&underline('Horizontal and Spatial Temporal Information Visualisation Techniques', '='));
print(&wrapText('Participant temporal progression orientation percentage matching expected outcome frequency distribution.'));
```

```
print(&frequencyGraph(\%participantResponseVsExpectedOutcomePercentageFrequency));
print(&wrapText('100% indicates temporal progression orientation matches expected outcome for all questions, where as 0% indicates reversed temporal progression orien
tation to expected outcome for all questions.'));
print(&basicStatisticalAnalysisWithBoundsReport(@participantResponseVsExpectedOutcomePercentage));
print("\n\n");
#
# Graph participant temporal progression orientation percentage frequency distribution.
#
%graphDetail = ();
$graphDetail{'title'} = 'Horizontal and Spatial Temporal Visualisation Techniques';
$graphDetail{'axisTickValues'} = '0 10 20 30 40 50 60 70 80 90 100';
$graphDetail{'axisTickLabels'} = '0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%';
$graphDetail{'label'} = 'Temporal progression orientation matching expected outcome.';
$graphDetail{'orientate'} = 0;
$graphDetail{'filename'} = 'graphHorizontalSpatial.png';
&graph([\%participantResponseVsExpectedOutcomePercentageFrequency], \%graphDetail);

#-----------------------------------------------------------------------
# Participant horizontal temporal progression orientation analysis.
#-----------------------------------------------------------------------
#
@participantLeftRightOrientationPercentage = &participantResponseVsExpectedOutcomePercentage(\@participant, \@participantData, [$VISUALISATION_TECHNIQUE{'Time Line'}]
, \@EXPECTED_OUTCOME);
#
# Calculate participant horizontal left/right temporal progression orientation percentage frequency distribution.
#
%participantLeftRightOrientationPercentageFrequency = &initialiseFrequencyData(&expectedOutcomeCount([$VISUALISATION_TECHNIQUE{'Time Line'}], \@EXPECTED_OUTCOME));
$participantLeftRightOrientationPercentageFrequency = Statistics::Frequency->new(\%participantLeftRightOrientationPercentageFrequency);
$participantLeftRightOrientationPercentageFrequency->add_data(@participantLeftRightOrientationPercentage);
%participantLeftRightOrientationPercentageFrequency = $participantLeftRightOrientationPercentageFrequency->frequencies;
@participantLeftRightOrientationPercentageFrequency = &frequencyHashToFrequencyArray(\%participantLeftRightOrientationPercentageFrequency);
#
# Binomial
#
@binomialDistributionFrequency = &binomialDistribution(scalar(@participantData), scalar(@{$EXPECTED_OUTCOME[$VISUALISATION_TECHNIQUE{'Time Line'}]}), 0.5);
%binomialDistributionFrequency = &initialiseFrequencyData(\@binomialDistributionFrequency);
#
# Display participant horizontal left/right temporal progression orientation percentage frequency distribution graph.
#
print(&underline('Time Line', '='));
print(&wrapText('Participant horizontal left/right temporal progression orientation percentage frequency distribution'));
print(&frequencyGraph(\%participantLeftRightOrientationPercentageFrequency));
print(&wrapText('100% indicates a left to right temporal progression orientation for all questions, 0% indicates a right to left orientation.'));
#
# Statistical analysis.
#
print(&basicStatisticalAnalysisReport(@participantLeftRightOrientationPercentage));
print(&chiSquareReport(\@participantLeftRightOrientationPercentageFrequency, \@binomialDistributionFrequency));
print("\n\n");
#
# Graph participant horizontal left/right temporal progression orientation percentage frequency distribution.
#
%graphDetail = ();
```

```
$graphDetail{'title'} = 'TIME LINE';
$graphDetail{'axisLeftTickLabel'} = 'Left';
$graphDetail{'axisRightTickLabel'} = 'Right';
$graphDetail{'label'} = 'Temporal progression orientation. Past on the left to the past on the right.';
$graphDetail{'filename'} = 'graphTimeLine.png';
&graph([\%participantLeftRightOrientationPercentageFrequency], \%graphDetail);
#
# Graph participant horizontal left/right temporal progression orientation percentage vs random binomial frequency distribution.
#
$graphDetail{'title'} = 'TIME LINE - Observed vs Random Binomial Distribution';
$graphDetail{'filename'} = 'graphTimeLineBinomial.png';
&graph([\%participantLeftRightOrientationPercentageFrequency, \%binomialDistributionFrequency], \%graphDetail);

#------------------------------------------------------------------------
# Participant spatial temporal progression orientation in 3D analysis.
#------------------------------------------------------------------------
#
@participantSpatialOrientationPercentage = &participantResponseVsExpectedOutcomePercentage(\@participant, \@participantData, [$VISUALISATION_TECHNIQUE{'3D'}], \@EXPEC
TED_OUTCOME);
#
# Calculate participant spatial temporal progression orientation percentage frequency distribution.
#
%participantSpatialOrientationPercentageFrequency = &initialiseFrequencyData(&expectedOutcomeCount([$VISUALISATION_TECHNIQUE{'3D'}], \@EXPECTED_OUTCOME));
$participantSpatialOrientationPercentageFrequency = Statistics::Frequency->new(\%participantSpatialOrientationPercentageFrequency);
$participantSpatialOrientationPercentageFrequency->add_data(@participantSpatialOrientationPercentage);
%participantSpatialOrientationPercentageFrequency = $participantSpatialOrientationPercentageFrequency->frequencies;
@participantSpatialOrientationPercentageFrequency = &frequencyHashToFrequencyArray(\%participantSpatialOrientationPercentageFrequency);
#
# Binomial
#
@binomialDistributionFrequency = &binomialDistribution(scalar(@participantData), scalar(@{$EXPECTED_OUTCOME[$VISUALISATION_TECHNIQUE{'3D'}]}), 0.5);
%binomialDistributionFrequency = &initialiseFrequencyData(\@binomialDistributionFrequency);
#
# Display participant spatial temporal progression orientation percentage frequency distribution graph.
#
print(&underline(' 3D ', '='));
print(&wrapText('Participant spatial temporal progression orientation percentage frequency distribution.'));
print(&frequencyGraph(\%participantSpatialOrientationPercentageFrequency));
print(&wrapText('100% indicates a spatial temporal progression orientation where the greater the depth the greater the age of the object, where as 0% indicates a spat
ial temporal progression orientation where the object in the foreground is the older.'));
#
# Statistical analysis
#
print(&basicStatisticalAnalysisReport(@participantSpatialOrientationPercentage));
print(&chiSquareReport(\@participantSpatialOrientationPercentageFrequency, \@binomialDistributionFrequency));
print("\n\n");
#
# Graph participant spatial temporal progression orientation percentage frequency distribution.
#
%graphDetail = ();
$graphDetail{'title'} = 'SPATIAL 3D';
$graphDetail{'rangeMax'} = 40;
$graphDetail{'filename'} = 'graphSpatial3d.png';
```

```
&graph([\%participantSpatialOrientationPercentageFrequency], \%graphDetail);
#
# Graph participant spatial temporal progression orientation percentage vs random binomial frequency distribution.
#
$graphDetail{'title'} = 'SPATIAL 3D - Observed vs Random Binomial Distribution';
$graphDetail{'filename'} = 'graphSpatial3dBinomial.png';
&graph([\%participantSpatialOrientationPercentageFrequency, \%binomialDistributionFrequency], \%graphDetail);

#----------------------------------------------------------------------
# Participant spatial 3D right wall temporal progression orientation analysis.
#----------------------------------------------------------------------
#
@participantSpatialOrientationPercentage = &participantResponseVsExpectedOutcomePercentage(\@participant, \@participantData, [$VISUALISATION_TECHNIQUE{'3D Right Wall'
}], \@EXPECTED_OUTCOME);
#
# Calculate participant spatial temporal progression orientation percentage frequency distribution.
#
%participantSpatialOrientationPercentageFrequency = &initialiseFrequencyData(&expectedOutcomeCount([$VISUALISATION_TECHNIQUE{'3D Right Wall'}], \@EXPECTED_OUTCOME));
$participantSpatialOrientationPercentageFrequency = Statistics::Frequency->new(\%participantSpatialOrientationPercentageFrequency);
$participantSpatialOrientationPercentageFrequency->add_data(@participantSpatialOrientationPercentage);
%participantSpatialOrientationPercentageFrequency = $participantSpatialOrientationPercentageFrequency->frequencies;
@participantSpatialOrientationPercentageFrequency = &frequencyHashToFrequencyArray(\%participantSpatialOrientationPercentageFrequency);
#
# Binomial
#
@binomialDistributionFrequency = &binomialDistribution(scalar(@participantData), scalar(@{$EXPECTED_OUTCOME[$VISUALISATION_TECHNIQUE{'3D Right Wall'}]}), 0.5);
%binomialDistributionFrequency = &initialiseFrequencyData(\@binomialDistributionFrequency);
#
# Display participant spatial temporal progression orientation percentage frequency distribution graph.
#
print(&underline('3D Right Wall', '='));
print(&wrapText('Participant spatial temporal progression orientation percentage frequency distribution.'));
print(&frequencyGraph(\%participantSpatialOrientationPercentageFrequency));
print(&wrapText('100% indicates a spatial temporal progression orientation where the greater the depth the greater the age of the object, where as 0% indicates a spat
ial temporal progression orientation where the object in the foreground is the older.'));
#
# Statistical analysis
#
print(&basicStatisticalAnalysisReport(@participantSpatialOrientationPercentage));
print(&chiSquareReport(\@participantSpatialOrientationPercentageFrequency, \@binomialDistributionFrequency));
print("\n\n");
#
# Graph participant spatial temporal progression orientation percentage frequency distribution.
#
%graphDetail = ();
$graphDetail{'title'} = 'SPATIAL RIGHT WALL';
$graphDetail{'filename'} = 'graphSpatialRightWall.png';
&graph([\%participantSpatialOrientationPercentageFrequency], \%graphDetail);
#
# Graph participant spatial temporal progression orientation percentage vs random binomial frequency distribution.
#
$graphDetail{'title'} = 'SPATIAL RIGHT WALL - Observed vs Random Binomial Distribution';
$graphDetail{'filename'} = 'graphSpatialRightWallBinomial.png';
```

```
&graph([\%participantSpatialOrientationPercentageFrequency, \%binomialDistributionFrequency], \%graphDetail);

#-----------------------------------------------------------------------
# Participant spatial 3D left wall temporal progression orientation analysis.
#-----------------------------------------------------------------------
#
@participantSpatialOrientationPercentage = &participantResponseVsExpectedOutcomePercentage(\@participant, \@participantData, [$VISUALISATION_TECHNIQUE{'3D Left Wall'}
], \@EXPECTED_OUTCOME);
#
# Calculate participant spatial temporal progression orientation percentage frequency distribution.
#
%participantSpatialOrientationPercentageFrequency = &initialiseFrequencyData(&expectedOutcomeCount([$VISUALISATION_TECHNIQUE{'3D Left Wall'}], \@EXPECTED_OUTCOME));
$participantSpatialOrientationPercentageFrequency = Statistics::Frequency->new(\%participantSpatialOrientationPercentageFrequency);
$participantSpatialOrientationPercentageFrequency->add_data(@participantSpatialOrientationPercentage);
%participantSpatialOrientationPercentageFrequency = $participantSpatialOrientationPercentageFrequency->frequencies;
@participantSpatialOrientationPercentageFrequency = &frequencyHashToFrequencyArray(\%participantSpatialOrientationPercentageFrequency);
#
# Binomial
#
@binomialDistributionFrequency = &binomialDistribution(scalar(@participantData), scalar(@{$EXPECTED_OUTCOME[$VISUALISATION_TECHNIQUE{'3D Right Wall'}]}), 0.5);
%binomialDistributionFrequency = &initialiseFrequencyData(\@binomialDistributionFrequency);
#
# Display participant spatial temporal progression orientation percentage frequency distribution graph.
#
print(&underline('3D Left Wall', '='));
print(&wrapText('Participant spatial temporal progression orientation percentage frequency distribution.'));
print(&frequencyGraph(\%participantSpatialOrientationPercentageFrequency));
print(&wrapText('100% indicates a spatial temporal progression orientation where the greater the depth the greater the age of the object, where as 0% indicates a spat
ial temporal progression orientation where the object in the foreground is the older.'));
#
# Statistical analysis
#
print(&basicStatisticalAnalysisReport(@participantSpatialOrientationPercentage));
print(&chiSquareReport(\@participantSpatialOrientationPercentageFrequency, \@binomialDistributionFrequency));
print("\n\n");
#
# Graph participant spatial temporal progression orientation percentage frequency distribution.
#
%graphDetail = ();
$graphDetail{'title'} = 'SPATIAL LEFT WALL';
$graphDetail{'filename'} = 'graphSpatialLeftWall.png';
&graph([\%participantSpatialOrientationPercentageFrequency], \%graphDetail);
#
# Graph participant spatial temporal progression orientation percentage vs random binomial frequency distribution.
#
$graphDetail{'title'} = 'SPATIAL LEFT WALL - Observed vs Random Binomial Distribution';
$graphDetail{'filename'} = 'graphSpatialLeftWallBinomial.png';
&graph([\%participantSpatialOrientationPercentageFrequency, \%binomialDistributionFrequency], \%graphDetail);

#-----------------------------------------------------------------------
# Participant spatial 3D wall temporal progression orientation analysis.
#-----------------------------------------------------------------------
#
```

```
@participantSpatialOrientationPercentage = &participantResponseVsExpectedOutcomePercentage(\@participant, \@participantData, [$VISUALISATION_TECHNIQUE{'3D Right Wall'
}, $VISUALISATION_TECHNIQUE{'3D Left Wall'}], \@EXPECTED_OUTCOME);
#
# Calculate participant spatial temporal progression orientation percentage frequency distribution.
#
%participantSpatialOrientationPercentageFrequency = &initialiseFrequencyData(&expectedOutcomeCount([$VISUALISATION_TECHNIQUE{'3D Right Wall'}, $VISUALISATION_TECHNIQU
E{'3D Left Wall'}], \@EXPECTED_OUTCOME));
$participantSpatialOrientationPercentageFrequency = Statistics::Frequency->new(\%participantSpatialOrientationPercentageFrequency);
$participantSpatialOrientationPercentageFrequency->add_data(@participantSpatialOrientationPercentage);
%participantSpatialOrientationPercentageFrequency = $participantSpatialOrientationPercentageFrequency->frequencies;
%participantSpatialOrientationPercentageFrequency = &consolidatePercentHashKeys(\%participantSpatialOrientationPercentageFrequency, 6) if $option{n};
#
# Display participant spatial temporal progression orientation percentage frequency distribution graph.
#
print(&underline('3D Wall Combined', '='));
print(&wrapText('Participant spatial temporal progression orientation percentage frequency distribution.'));
print(&frequencyGraph(\%participantSpatialOrientationPercentageFrequency));
print(&wrapText('100% indicates a spatial temporal progression orientation where the greater the depth the greater the age of the object, where as 0% indicates a spat
ial temporal progression orientation where the object in the foreground is the older.'));
#
# Statistical analysis
#
print(&basicStatisticalAnalysisReport(@participantSpatialOrientationPercentage));
print("\n\n");
#
# Graph participant spatial temporal progression orientation percentage frequency distribution.
#
%graphDetail = ();
$graphDetail{'title'} = 'SPATIAL WALL';
$graphDetail{'filename'} = 'graphSpatialWall.png';
&graph([\%participantSpatialOrientationPercentageFrequency], \%graphDetail);

#-----------------------------------------------------------------------
# Participant spatial temporal progression orientation analysis.
#-----------------------------------------------------------------------
#
@participantSpatialOrientationPercentage = &participantResponseVsExpectedOutcomePercentage(\@participant, \@participantData, [$VISUALISATION_TECHNIQUE{'3D'}, $VISUALI
SATION_TECHNIQUE{'3D Right Wall'}, $VISUALISATION_TECHNIQUE{'3D Left Wall'}], \@EXPECTED_OUTCOME);
#
# Calculate participant spatial temporal progression orientation percentage frequency distribution.
#
%participantSpatialOrientationPercentageFrequency = &initialiseFrequencyData(&expectedOutcomeCount([$VISUALISATION_TECHNIQUE{'3D'}, $VISUALISATION_TECHNIQUE{'3D Right
 Wall'}, $VISUALISATION_TECHNIQUE{'3D Left Wall'}], \@EXPECTED_OUTCOME));
$participantSpatialOrientationPercentageFrequency = Statistics::Frequency->new(\%participantSpatialOrientationPercentageFrequency);
$participantSpatialOrientationPercentageFrequency->add_data(@participantSpatialOrientationPercentage);
%participantSpatialOrientationPercentageFrequency = $participantSpatialOrientationPercentageFrequency->frequencies;
%participantSpatialOrientationPercentageFrequency = &consolidatePercentHashKeys(\%participantSpatialOrientationPercentageFrequency, 6) if $option{n};
#
# Display participant spatial temporal progression orientation percentage frequency distribution graph.
#
print(&underline('Spatial', '='));
print(&wrapText('Participant spatial temporal progression orientation percentage frequency distribution.'));
print(&frequencyGraph(\%participantSpatialOrientationPercentageFrequency));
```

```
print(&wrapText('100% indicates a spatial temporal progression orientation where the greater the depth the greater the age of the object, where as 0% indicates a spat
ial temporal progression orientation where the object in the foreground is the older.'));
#
# Statistical analysis.
#
print(&basicStatisticalAnalysisReport(@participantSpatialOrientationPercentage));
print("\n\n");
#
# Graph participant spatial temporal progression orientation percentage frequency distribution.
#
%graphDetail = ();
$graphDetail{'title'} = 'SPATIAL';
$graphDetail{'filename'} = 'graphSpatial.png';
&graph([\%participantSpatialOrientationPercentageFrequency], \%graphDetail);

#=======================================================================
#
# Analysis of participants with a background spatial temporal progression orientation in the 3D.
#
#=======================================================================

#-----------------------------------------------------------------------
# Get list of participants with a spatial temporal progression orientation in 3D to a degree of 100%.
#-----------------------------------------------------------------------
#
@spatialOrientatedParticipant = &participant(\@participant, \@participantData, [$VISUALISATION_TECHNIQUE{'3D'}], [100], \@EXPECTED_OUTCOME);
#
# Total number of participants with a spatial temporal progression orientation in 3D to a degree of 100%.
#
print("\n\n" . &wrapText(sprintf("Number of particpants with a spatial temporal progression orientation of the past in the background in the 3D information visualisat
ions : %d", scalar(@spatialOrientatedParticipant))) . "\n\n\n");

#-----------------------------------------------------------------------
# Participant spatial temporal progression orientation in 3D analysis.
#-----------------------------------------------------------------------
#
@participantSpatialOrientationPercentage = &participantResponseVsExpectedOutcomePercentage(\@spatialOrientatedParticipant, \@participantData, [$VISUALISATION_TECHNIQU
E{'3D'}], \@EXPECTED_OUTCOME);
#
# Calculate participant spatial temporal progression orientation percentage frequency distribution.
#
%participantSpatialOrientationPercentageFrequency = &initialiseFrequencyData(&expectedOutcomeCount([$VISUALISATION_TECHNIQUE{'3D'}], \@EXPECTED_OUTCOME));
$participantSpatialOrientationPercentageFrequency = Statistics::Frequency->new(\%participantSpatialOrientationPercentageFrequency);
$participantSpatialOrientationPercentageFrequency->add_data(@participantSpatialOrientationPercentage);
%participantSpatialOrientationPercentageFrequency = $participantSpatialOrientationPercentageFrequency->frequencies;
#
# Display participant spatial temporal progression orientation percentage frequency distribution graph.
#
print(&underline('100% Spatial 3D', '='));
print(&wrapText('Participant spatial temporal progression orientation percentage frequency distribution.'));
print(&frequencyGraph(\%participantSpatialOrientationPercentageFrequency));
print(&wrapText('100% indicates a spatial temporal progression orientation where the greater the depth the greater the age of the object, where as 0% indicates a spat
ial temporal progression orientation where the object in the foreground is the older.'));
```

```
#
# Statistical analysis
#
print(&basicStatisticalAnalysisReport(@participantSpatialOrientationPercentage));
print("\n\n");
#
# Graph participant spatial temporal progression orientation percentage frequency distribution.
#
%graphDetail = ();
$graphDetail{'title'} = 'SPATIAL ORIENTATED DEPTH FOR THE PAST - 3D';
$graphDetail{'filename'} = 'graph100percentSpatial3d.png';
&graph([\%participantSpatialOrientationPercentageFrequency], \%graphDetail);

#----------------------------------------------------------------------
# Participant spatial 3D right wall temporal progression orientation analysis.
#----------------------------------------------------------------------
#
@participantSpatialOrientationPercentage = &participantResponseVsExpectedOutcomePercentage(\@spatialOrientatedParticipant, \@participantData, [$VISUALISATION_TECHNIQU
E{'3D Right Wall'}], \@EXPECTED_OUTCOME);
#
# Calculate participant spatial temporal progression orientation percentage frequency distribution.
#
%participantSpatialOrientationPercentageFrequency = &initialiseFrequencyData(&expectedOutcomeCount([$VISUALISATION_TECHNIQUE{'3D Right Wall'}], \@EXPECTED_OUTCOME));
$participantSpatialOrientationPercentageFrequency = Statistics::Frequency->new(\%participantSpatialOrientationPercentageFrequency);
$participantSpatialOrientationPercentageFrequency->add_data(@participantSpatialOrientationPercentage);
%participantSpatialOrientationPercentageFrequency = $participantSpatialOrientationPercentageFrequency->frequencies;
#
# Display participant spatial temporal progression orientation percentage frequency distribution graph.
#
print(&underline('100% Spatial 3D - 3D Right Wall', '='));
print(&wrapText('Participant spatial temporal progression orientation percentage frequency distribution.'));
print(&frequencyGraph(\%participantSpatialOrientationPercentageFrequency));
print(&wrapText('100% indicates a spatial temporal progression orientation where the greater the depth the greater the age of the object, where as 0% indicates a spat
ial temporal progression orientation where the object in the foreground is the older.'));
#
# Statistical analysis
#
print(&basicStatisticalAnalysisReport(@participantSpatialOrientationPercentage));
print("\n\n");
#
# Graph participant spatial temporal progression orientation percentage frequency distribution.
#
%graphDetail = ();
$graphDetail{'title'} = 'SPATIAL ORIENTATED DEPTH FOR THE PAST - Spatial Right Wall';
$graphDetail{'filename'} = 'graph100percentSpatialSpatialRightWall.png';
&graph([\%participantSpatialOrientationPercentageFrequency], \%graphDetail);

#----------------------------------------------------------------------
# Participant spatial 3D left wall temporal progression orientation analysis.
#----------------------------------------------------------------------
#
@participantSpatialOrientationPercentage = &participantResponseVsExpectedOutcomePercentage(\@spatialOrientatedParticipant, \@participantData, [$VISUALISATION_TECHNIQU
E{'3D Left Wall'}], \@EXPECTED_OUTCOME);
```

```
#
# Calculate participant spatial temporal progression orientation percentage frequency distribution.
#
%participantSpatialOrientationPercentageFrequency = &initialiseFrequencyData(&expectedOutcomeCount([$VISUALISATION_TECHNIQUE{'3D Left Wall'}], \@EXPECTED_OUTCOME));
$participantSpatialOrientationPercentageFrequency = Statistics::Frequency->new(\%participantSpatialOrientationPercentageFrequency);
$participantSpatialOrientationPercentageFrequency->add_data(@participantSpatialOrientationPercentage);
%participantSpatialOrientationPercentageFrequency = $participantSpatialOrientationPercentageFrequency->frequencies;
#
# Display participant spatial temporal progression orientation percentage frequency distribution graph.
#
print(&underline('100% Spatial 3D - 3D Left Wall', '='));
print(&wrapText('Participant spatial temporal progression orientation percentage frequency distribution.'));
print(&frequencyGraph(\%participantSpatialOrientationPercentageFrequency));
print(&wrapText('100% indicates a spatial temporal progression orientation where the greater the depth the greater the age of the object, where as 0% indicates a spat
ial temporal progression orientation where the object in the foreground is the older.'));
#
# Statistical analysis
#
print(&basicStatisticalAnalysisReport(@participantSpatialOrientationPercentage));
print("\n\n");
#
# Graph participant spatial temporal progression orientation percentage frequency distribution.
#
%graphDetail = ();
$graphDetail{'title'} = 'SPATIAL ORIENTATED DEPTH FOR THE PAST - Spatial Left Wall';
$graphDetail{'rangeMax'} = 20;
$graphDetail{'filename'} = 'graph100percentSpatialSpatialLeftWall.png';
&graph([\%participantSpatialOrientationPercentageFrequency], \%graphDetail);

#----------------------------------------------------------------------
# Participant spatial 3D wall temporal progression orientation analysis.
#----------------------------------------------------------------------
#
@participantSpatialOrientationPercentage = &participantResponseVsExpectedOutcomePercentage(\@spatialOrientatedParticipant, \@participantData, [$VISUALISATION_TECHNIQU
E{'3D Right Wall'}, $VISUALISATION_TECHNIQUE{'3D Left Wall'}], \@EXPECTED_OUTCOME);
#
# Calculate participant spatial temporal progression orientation percentage frequency distribution.
#
%participantSpatialOrientationPercentageFrequency = &initialiseFrequencyData(&expectedOutcomeCount([$VISUALISATION_TECHNIQUE{'3D Right Wall'}, $VISUALISATION_TECHNIQU
E{'3D Left Wall'}], \@EXPECTED_OUTCOME));
$participantSpatialOrientationPercentageFrequency = Statistics::Frequency->new(\%participantSpatialOrientationPercentageFrequency);
$participantSpatialOrientationPercentageFrequency->add_data(@participantSpatialOrientationPercentage);
%participantSpatialOrientationPercentageFrequency = $participantSpatialOrientationPercentageFrequency->frequencies;
%participantSpatialOrientationPercentageFrequency = &consolidatePercentHashKeys(\%participantSpatialOrientationPercentageFrequency, 6) if $option{n};
#
# Display participant spatial temporal progression orientation percentage frequency distribution graph.
#
print(&underline('100% Spatial 3D - 3D Wall Combined', '='));
print(&wrapText('Participant spatial temporal progression orientation percentage frequency distribution.'));
print(&frequencyGraph(\%participantSpatialOrientationPercentageFrequency));
print(&wrapText('100% indicates a spatial temporal progression orientation where the greater the depth the greater the age of the object, where as 0% indicates a spat
ial temporal progression orientation where the object in the foreground is the older.'));
#
```

```
# Statistical analysis
#
print(&basicStatisticalAnalysisReport(@participantSpatialOrientationPercentage));
print("\n\n");
#
# Graph participant spatial temporal progression orientation percentage frequency distribution.
#
%graphDetail = ();
$graphDetail{'title'} = 'SPATIAL ORIENTATED DEPTH FOR THE PAST - Spatial Wall';
$graphDetail{'rangeMax'} = 20;
$graphDetail{'filename'} = 'graph100percentSpatialSpatialWall.png';
&graph([\%participantSpatialOrientationPercentageFrequency], \%graphDetail);

#---------------------------------------------------------------------
# Participant spatial temporal progression orientation analysis.
#---------------------------------------------------------------------
#
@participantSpatialOrientationPercentage = &participantResponseVsExpectedOutcomePercentage(\@spatialOrientatedParticipant, \@participantData, [$VISUALISATION_TECHNIQU
E{'3D'}, $VISUALISATION_TECHNIQUE{'3D Right Wall'}, $VISUALISATION_TECHNIQUE{'3D Left Wall'}], \@EXPECTED_OUTCOME);
#
# Calculate participant spatial temporal progression orientation percentage frequency distribution.
#
%participantSpatialOrientationPercentageFrequency = &initialiseFrequencyData(&expectedOutcomeCount([$VISUALISATION_TECHNIQUE{'3D'}, $VISUALISATION_TECHNIQUE{'3D Right
 Wall'}, $VISUALISATION_TECHNIQUE{'3D Left Wall'}], \@EXPECTED_OUTCOME));
$participantSpatialOrientationPercentageFrequency = Statistics::Frequency->new(\%participantSpatialOrientationPercentageFrequency);
$participantSpatialOrientationPercentageFrequency->add_data(@participantSpatialOrientationPercentage);
%participantSpatialOrientationPercentageFrequency = $participantSpatialOrientationPercentageFrequency->frequencies;
%participantSpatialOrientationPercentageFrequency = &consolidatePercentHashKeys(\%participantSpatialOrientationPercentageFrequency, 6) if $option{n};
#
# Display participant spatial temporal progression orientation percentage frequency distribution graph.
#
print(&underline('100% Spatial 3D - Spatial', '='));
print(&wrapText('Participant spatial temporal progression orientation percentage frequency distribution.'));
print(&frequencyGraph(\%participantSpatialOrientationPercentageFrequency));
print(&wrapText('100% indicates a spatial temporal progression orientation where the greater the depth the greater the age of the object, where as 0% indicates a spat
ial temporal progression orientation where the object in the foreground is the older.'));
#
# Statistical analysis.
#
print(&basicStatisticalAnalysisReport(@participantSpatialOrientationPercentage));
print("\n\n");
#
# Graph participant spatial temporal progression orientation percentage frequency distribution.
#
%graphDetail = ();
$graphDetail{'title'} = 'SPATIAL ORIENTATED DEPTH FOR THE PAST - Spatial';
$graphDetail{'rangeMax'} = 20;
$graphDetail{'filename'} = 'graph100percentSpatialSpatial.png';
&graph([\%participantSpatialOrientationPercentageFrequency], \%graphDetail);

#=====================================================================
#
# Analysis of participants with a dominant background spatial temporal progression orientation in the 3D.
```

```
#
#======================================================================

#----------------------------------------------------------------------
# Get list of participants with a spatial temporal progression orientation in 3D to a degree of 80% plus.
#----------------------------------------------------------------------
#
@spatialOrientatedParticipant = &participant(\@participant, \@participantData, [$VISUALISATION_TECHNIQUE{'3D'}], [80, 100], \@EXPECTED_OUTCOME);
#
# Total number of participants with a spatial temporal progression orientation in 3D to a degree of 80% plus.
#
print("\n\n" . &wrapText(sprintf("Number of particpants with a dominant spatial temporal progression orientation of the past in the background in the 3D information v
isualisations : %d", scalar(@spatialOrientatedParticipant))) . "\n\n\n");

#----------------------------------------------------------------------
# Participant spatial temporal progression orientation in 3D analysis.
#----------------------------------------------------------------------
#
@participantSpatialOrientationPercentage = &participantResponseVsExpectedOutcomePercentage(\@spatialOrientatedParticipant, \@participantData, [$VISUALISATION_TECHNIQU
E{'3D'}], \@EXPECTED_OUTCOME);
#
# Calculate participant spatial temporal progression orientation percentage frequency distribution.
#
%participantSpatialOrientationPercentageFrequency = &initialiseFrequencyData(&expectedOutcomeCount([$VISUALISATION_TECHNIQUE{'3D'}], \@EXPECTED_OUTCOME));
$participantSpatialOrientationPercentageFrequency = Statistics::Frequency->new(\%participantSpatialOrientationPercentageFrequency);
$participantSpatialOrientationPercentageFrequency->add_data(@participantSpatialOrientationPercentage);
%participantSpatialOrientationPercentageFrequency = $participantSpatialOrientationPercentageFrequency->frequencies;
#
# Display participant spatial temporal progression orientation percentage frequency distribution graph.
#
print(&underline('Dominant Spatial 3D', '='));
print(&wrapText('Participant spatial temporal progression orientation percentage frequency distribution.'));
print(&frequencyGraph(\%participantSpatialOrientationPercentageFrequency));
print(&wrapText('100% indicates a spatial temporal progression orientation where the greater the depth the greater the age of the object, where as 0% indicates a spat
ial temporal progression orientation where the object in the foreground is the older.'));
#
# Statistical analysis
#
print(&basicStatisticalAnalysisReport(@participantSpatialOrientationPercentage));
print("\n\n");
#
# Graph participant spatial temporal progression orientation percentage frequency distribution.
#
%graphDetail = ();
$graphDetail{'title'} = 'DOMINANT SPATIAL ORIENTATED DEPTH FOR THE PAST - 3D';
$graphDetail{'filename'} = 'graph80plusPercentSpatial3d.png';
&graph([\%participantSpatialOrientationPercentageFrequency], \%graphDetail);

#----------------------------------------------------------------------
# Participant spatial 3D right wall temporal progression orientation analysis.
#----------------------------------------------------------------------
#
@participantSpatialOrientationPercentage = &participantResponseVsExpectedOutcomePercentage(\@spatialOrientatedParticipant, \@participantData, [$VISUALISATION_TECHNIQU
```

```
E{'3D Right Wall'}], \@EXPECTED_OUTCOME);
#
# Calculate participant spatial temporal progression orientation percentage frequency distribution.
#
%participantSpatialOrientationPercentageFrequency = &initialiseFrequencyData(&expectedOutcomeCount([$VISUALISATION_TECHNIQUE{'3D Right Wall'}], \@EXPECTED_OUTCOME));
$participantSpatialOrientationPercentageFrequency = Statistics::Frequency->new(\%participantSpatialOrientationPercentageFrequency);
$participantSpatialOrientationPercentageFrequency->add_data(@participantSpatialOrientationPercentage);
%participantSpatialOrientationPercentageFrequency = $participantSpatialOrientationPercentageFrequency->frequencies;
#
# Display participant spatial temporal progression orientation percentage frequency distribution graph.
#
print(&underline('Dominant Spatial 3D - 3D Right Wall', '='));
print(&wrapText('Participant spatial temporal progression orientation percentage frequency distribution.'));
print(&frequencyGraph(\%participantSpatialOrientationPercentageFrequency));
print(&wrapText('100% indicates a spatial temporal progression orientation where the greater the depth the greater the age of the object, where as 0% indicates a spat
ial temporal progression orientation where the object in the foreground is the older.'));
#
# Statistical analysis
#
print(&basicStatisticalAnalysisReport(@participantSpatialOrientationPercentage));
print("\n\n");
#
# Graph participant spatial temporal progression orientation percentage frequency distribution.
#
%graphDetail = ();
$graphDetail{'title'} = 'DOMINANT SPATIAL ORIENTATED DEPTH FOR THE PAST - Spatial Right Wall';
$graphDetail{'filename'} = 'graph80plusPercentSpatialSpatialRightWall.png';
&graph([\%participantSpatialOrientationPercentageFrequency], \%graphDetail);

#----------------------------------------------------------------------
# Participant spatial 3D left wall temporal progression orientation analysis.
#----------------------------------------------------------------------
#
@participantSpatialOrientationPercentage = &participantResponseVsExpectedOutcomePercentage(\@spatialOrientatedParticipant, \@participantData, [$VISUALISATION_TECHNIQU
E{'3D Left Wall'}], \@EXPECTED_OUTCOME);
#
# Calculate participant spatial temporal progression orientation percentage frequency distribution.
#
%participantSpatialOrientationPercentageFrequency = &initialiseFrequencyData(&expectedOutcomeCount([$VISUALISATION_TECHNIQUE{'3D Left Wall'}], \@EXPECTED_OUTCOME));
$participantSpatialOrientationPercentageFrequency = Statistics::Frequency->new(\%participantSpatialOrientationPercentageFrequency);
$participantSpatialOrientationPercentageFrequency->add_data(@participantSpatialOrientationPercentage);
%participantSpatialOrientationPercentageFrequency = $participantSpatialOrientationPercentageFrequency->frequencies;
#
# Display participant spatial temporal progression orientation percentage frequency distribution graph.
#
print(&underline('Dominant Spatial 3D - 3D Left Wall', '='));
print(&wrapText('Participant spatial temporal progression orientation percentage frequency distribution.'));
print(&frequencyGraph(\%participantSpatialOrientationPercentageFrequency));
print(&wrapText('100% indicates a spatial temporal progression orientation where the greater the depth the greater the age of the object, where as 0% indicates a spat
ial temporal progression orientation where the object in the foreground is the older.'));
#
# Statistical analysis
#
```

```
print(&basicStatisticalAnalysisReport(@participantSpatialOrientationPercentage));
print("\n\n");
#
# Graph participant spatial temporal progression orientation percentage frequency distribution.
#
%graphDetail = ();
$graphDetail{'title'} = 'DOMINANT SPATIAL ORIENTATED DEPTH FOR THE PAST - Spatial Left Wall';
$graphDetail{'rangeMax'} = 20;
$graphDetail{'filename'} = 'graph80plusPercentSpatialSpatialLeftWall.png';
&graph([\%participantSpatialOrientationPercentageFrequency], \%graphDetail);

#-----------------------------------------------------------------------
# Participant spatial 3D wall temporal progression orientation analysis.
#-----------------------------------------------------------------------
#
@participantSpatialOrientationPercentage = &participantResponseVsExpectedOutcomePercentage(\@spatialOrientatedParticipant, \@participantData, [$VISUALISATION_TECHNIQU
E{'3D Right Wall'}, $VISUALISATION_TECHNIQUE{'3D Left Wall'}], \@EXPECTED_OUTCOME);
#
# Calculate participant spatial temporal progression orientation percentage frequency distribution.
#
%participantSpatialOrientationPercentageFrequency = &initialiseFrequencyData(&expectedOutcomeCount([$VISUALISATION_TECHNIQUE{'3D Right Wall'}, $VISUALISATION_TECHNIQU
E{'3D Left Wall'}], \@EXPECTED_OUTCOME));
$participantSpatialOrientationPercentageFrequency = Statistics::Frequency->new(\%participantSpatialOrientationPercentageFrequency);
$participantSpatialOrientationPercentageFrequency->add_data(@participantSpatialOrientationPercentage);
%participantSpatialOrientationPercentageFrequency = $participantSpatialOrientationPercentageFrequency->frequencies;
%participantSpatialOrientationPercentageFrequency = &consolidatePercentHashKeys(\%participantSpatialOrientationPercentageFrequency, 6) if $option{n};
#
# Display participant spatial temporal progression orientation percentage frequency distribution graph.
#
print(&underline('Dominant Spatial 3D - 3D Wall Combined', '='));
print(&wrapText('Participant spatial temporal progression orientation percentage frequency distribution.'));
print(&frequencyGraph(\%participantSpatialOrientationPercentageFrequency));
print(&wrapText('100% indicates a spatial temporal progression orientation where the greater the depth the greater the age of the object, where as 0% indicates a spat
ial temporal progression orientation where the object in the foreground is the older.'));
#
# Statistical analysis
#
print(&basicStatisticalAnalysisReport(@participantSpatialOrientationPercentage));
print("\n\n");
#
# Graph participant spatial temporal progression orientation percentage frequency distribution.
#
%graphDetail = ();
$graphDetail{'title'} = 'DOMINANT SPATIAL ORIENTATED DEPTH FOR THE PAST - Spatial Wall';
$graphDetail{'rangeMax'} = 20;
$graphDetail{'filename'} = 'graph80plusPercentSpatialSpatialWall.png';
&graph([\%participantSpatialOrientationPercentageFrequency], \%graphDetail);

#-----------------------------------------------------------------------
# Participant spatial temporal progression orientation analysis.
#-----------------------------------------------------------------------
#
@participantSpatialOrientationPercentage = &participantResponseVsExpectedOutcomePercentage(\@spatialOrientatedParticipant, \@participantData, [$VISUALISATION_TECHNIQU
```

```
E{'3D'}, $VISUALISATION_TECHNIQUE{'3D Right Wall'}, $VISUALISATION_TECHNIQUE{'3D Left Wall'}], \@EXPECTED_OUTCOME);
#
# Calculate participant spatial temporal progression orientation percentage frequency distribution.
#
%participantSpatialOrientationPercentageFrequency = &initialiseFrequencyData(&expectedOutcomeCount([$VISUALISATION_TECHNIQUE{'3D'}, $VISUALISATION_TECHNIQUE{'3D Right
 Wall'}, $VISUALISATION_TECHNIQUE{'3D Left Wall'}], \@EXPECTED_OUTCOME));
$participantSpatialOrientationPercentageFrequency = Statistics::Frequency->new(\%participantSpatialOrientationPercentageFrequency);
$participantSpatialOrientationPercentageFrequency->add_data(@participantSpatialOrientationPercentage);
%participantSpatialOrientationPercentageFrequency = $participantSpatialOrientationPercentageFrequency->frequencies;
%participantSpatialOrientationPercentageFrequency = &consolidatePercentHashKeys(\%participantSpatialOrientationPercentageFrequency, 6) if $option{n};
#
# Display participant spatial temporal progression orientation percentage frequency distribution graph.
#
print(&underline('Dominant Spatial 3D - Spatial', '='));
print(&wrapText('Participant spatial temporal progression orientation percentage frequency distribution.'));
print(&frequencyGraph(\%participantSpatialOrientationPercentageFrequency));
print(&wrapText('100% indicates a spatial temporal progression orientation where the greater the depth the greater the age of the object, where as 0% indicates a spat
ial temporal progression orientation where the object in the foreground is the older.'));
#
# Statistical analysis.
#
print(&basicStatisticalAnalysisReport(@participantSpatialOrientationPercentage));
print("\n\n");
#
# Graph participant spatial temporal progression orientation percentage frequency distribution.
#
%graphDetail = ();
$graphDetail{'title'} = 'DOMINANT SPATIAL ORIENTATED DEPTH FOR THE PAST - Spatial';
$graphDetail{'rangeMax'} = 20;
$graphDetail{'filename'} = 'graph80plusPercentSpatialSpatial.png';
&graph([\%participantSpatialOrientationPercentageFrequency], \%graphDetail);

#======================================================================
#
# Analysis complete.
#
#======================================================================

exit;
```