Courting the Visual Image: The Ability of Digital Graphics and Interfaces to Alter the Memory and Behaviour of the Viewer

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Abstract. An intrinsic connection exists between humans and the memories they create; they define who we are, where we came from and our accomplishments and failures. However, decades of research has shown how fragile human memory can be. Almost all human computer interfaces involve vision and most rely on vision as the primary means of passing information to the user [1]. It is worth considering that perhaps this specific form of media interaction requires special care and attention due to its inherently persuasive nature, and the undue reliance that the viewer may place on information presented through a (potentially photo-realistic) visualisation medium. Their influence on human memory and behaviour cannot be underestimated.

This paper will introduce research undertaken by the author over the past 25 years that has experimented with, and examined a range of visual based presentation technology into courtrooms all over the world. Courtrooms are environments where the decisions made (based on human memory and comprehension) can significantly affect the lives of others. This paper describes research undertaken to assess the effect of visual technology on users (in particular their memory and decision making abilities) and describes some of the issues raised by the experimental results. The work presented in this paper connects psychological research with human cognitive and perceptual processes and limitations, to allow the evaluation and optimisation of visual interfaces. The paper concludes with a discussion of the potential benefits and problems of designing interactive visual technology when considering the impact on human cognition.

Keywords: Visual images · Computer graphics · Psychology · Evidence · HCI

1 Introduction

In a modern courtroom, the presentation of forensic evidence by an expert witness can bring about the need for arduous descriptions by lawyers and experts to get across the specific details of complicated scientific, spatial and temporal data. Technological advances have also meant that experts have had to develop new ways to present such increasingly complex evidence in court. As courts begin see an increasingly use multi-media and cinematic displays, this has profound implications for the legal processes taking place that are intrinsically tied to the application of such technology. Courtrooms

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are environments where the decisions made (based on human memory and comprehension) can significantly affect the lives of others.

Digital visual evidence presentation systems (including digital displays, computer-generated graphical presentations and three-dimension virtual simulations) have already been used to present evidence and illustrate hypotheses based on scientific data in many jurisdictions [2]. These visual tools can be used to present evidence and illustrate hypotheses based on scientific data, or they may be used to depict the perception of a witness, and to illustrate what may have occurred (seen from a specific viewpoint) during a particular incident. Digital reconstruction technology may also be applied in a court to explore and illustrate 'what if' scenarios and questions, testing competing hypotheses and possibly exposing any inconsistencies and discrepancies within the evidence [3] Examples are shown in Fig. 1.

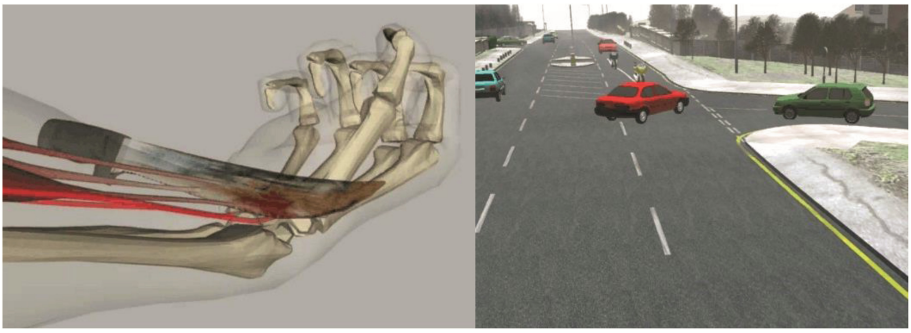

Fig. 1. Computer-generated evidential images from a suicide inquest and a road traffic accident.

The use of such computer-generated presentations in a court is sometimes viewed as nothing more than the current manifestation of the illustration of evidence and visualisation in a long history of evidential graphics used in litigation [2]. However, there are a number of fundamental implications inherent in the analysis of visual interfaces over textual/oral mediums and computer animations and interactive virtual simulations are potentially unparalleled in their capabilities for presenting complex evidence [4, 5]. The use of such enabling visualisation technology can affect the manner in which evidence is assimilated and correlated by the viewer. Their influence on human memory and behaviour cannot be underestimated. In many instances, visual media can potentially help make the evidence more relevant and easier to understand. In other cases it may be seen to be unfairly prejudicing a jury [3, 6, 7].

It is useful at this point to clarify the terms used to describe such technology. The standard form of evidence from such virtual environments usually consists of a series of still images and animations. In this context, the term 'computer animation' is often misused to describe an animation created from a virtual environment that is not based on the laws of physics, but is still represented as 'simulating' a given event.

The terms 'animation', 'scientific animation' and 'simulation' have had specific definitions in the reconstruction community for many years [8].

- '*Animation*' is a general term describing 'any presentation which consists of a series of graphical images being sequentially displayed, representing objects in different positions from one image to the next, which implies motion' (note: all the quotes in this paragraph are from Grimes). This term may be used to describe a presentation consisting of artist renditions or illustrated moving graphics, sometimes referred to as a 'cartoon animation'.
- The phrase '*Scientific Animation*' is consequently used to describe a more technically based presentation, and is defined as 'a computer animation that is based on the laws of physics and the appropriate equations of motion'. Velocities and positions are time integrals of the acceleration data, and the objects and environment in a scientific animation are properly and consistently scaled.
- In the reconstruction community, a '*Simulation*' is often defined as being based on the laws of physics and containing specific underlying equations. A simulation goes further than a scientific animation, and can be further defined as 'A model that predicts an outcome. The model may be a physical or a mathematical model, but the significant property is that a simulation predicts a future result' – for example a computation fluid dynamics model to predict smoke flow through an environment.

In summary, an 'animation' may only be illustrative or demonstrative evidence, whereas a 'scientific animation' is more technical, and relies upon scientific laws, and thus might be categorised as substantive evidence. A 'simulation' is more predictive in nature, and consists of data or forecasts that are usually created via a computer program.

The vast majority of people called to be on a jury have grown up watching visual media on screens: cinemas, televisions, computers and even on their mobile phones. Research has shown that many people tend to believe what they see in the mass media and merge mediated fictions into their beliefs about the world [9, 10]. The cognitive default when viewing visual media is to believe what is seen, only later engaging in the effort needed to suspend or reject belief. Pictures on a screen which move tend to be even easier to believe. These are usually more engaging and entertaining, and hence decrease the mental resources of the viewer which are available for doubt [11].

However, audiences receive visual information differently when they watch it on a screen compared to when they see it in real space and these differences can affect everything they see. This difference can be described in two contexts, firstly the way the screen frames and what the viewer sees; a physical border that limits and creates new relationships between the elements displayed inside it. Secondly, the visuals presented also act as a carrier of personal and cultural associations [12].

This ability of viewers to place undue reliance on visual evidence has profound implications for the use of any form of animated visual digital technology to present evidence in courtrooms [13]. The potential life-and-death weight of the issues means that those undertaking this important civic duty by acting as jurors need to able to make objective assessment of the evidence before making their decisions. The way the evidence presented must be probative, not unfairly prejudicial.

This paper gives a brief background to the use of animated visual digital technology in courtrooms and describes past research that has been undertaken to examine the impact any form of animated visual presentation has upon members of the jury. The paper also provides an extensive discussion of the issues arising from the use of animated

visual digital presentation, specifically those based on video game technology, in courtrooms. This includes an analysis of the emotional and psychological impact of the use of this technology, the creation of narrative through interaction with virtual environments and the influence of viewer perspective on the user experience. The paper concludes by comparing the advantages and disadvantages of using such a medium to present evidence.

2 Visual Evidence

Modern culture is dominated with images whose value may be simultaneously overdetermined and indeterminate, whose layers of significance can only be teased apart with difficulty. Different academic disciplines (including critical theory, psychology, education, media studies, art history, semiotics, etc.) have been developed to help explain how audiences interpret this visual imagery [2, 14]. Improvements in forensic science have led to an increasing amount of complex, technical evidence being presented in courts. The issues in question can be extremely complicated and difficult to explain without some form of graphical representation. A further survey by the American Bar Association found that members of a jury are often confused, bored, frustrated and overwhelmed by technical issues or complex facts [15]. Other research has indicated that the attention span of the average member of a jury in a court is, on average, only seven minutes (the same as the average attention span of a visitor to a website) [16–18].

Any visualisation or graphic can potentially be a valuable aid to help construe and convey a large amount of complex information. An American judge, Rubin highlighted the problem of retaining the interest of the jurors when he stated [19]:

> *'It isn't difficult to tell when jurors have lost interest … Such wandering attention is much less likely in a paperless trial, because the evidence is presented in a format jurors are used to watching … I have noticed repeatedly that when a document is displayed on the monitors, the jurors sit up and pay attention. Such attention is far greater than that given to a document which they cannot see as it is being discussed by the attorney and the witnesses …'.*

This comment illustrates the perceived need to reduce lengthy verbal explanations and increase the use of visual tools for a media-literate modern audience. This, in turn, offers a lawyer the possibility of improving the capacity of a jury to retain the evidence they present, to maintain their interest in the proceedings, and to allow the jury to understand the nature of the case more fully [20, 21].

In courtroom settings, static images such as diagrams, plans and charts have been traditionally used to explain the testimony of an expert witness. A number of modern expert witnesses now provide animated multimedia explanations illustrating their evidence. Such forensic animations or virtual reconstructions can be seen as an advance due to their unique ability to visually illustrate and animate visually the passing of time. This extra temporal dimension can be extremely useful when explaining a chronological sequence of events, such as the reconstruction of the occurrences leading up to a vehicle collision. In this case the dynamic movement of the vehicles involved in the collision may be dependent on complicated engineering or mathematical principles that are

potentially difficult to explain to members of the jury – but easy to understand when visually represented in an animated, photo-realistic reconstruction [22].

A particularly relevant aspect of the technology under discussion is the ability to visualise unseen or imaginary environments. In a courtroom context this manifests itself as the ability to visualise evidential information that may not be naturally or readily visible to the naked eye. The virtual camera can break free of the physical restrictions restraining real world cameras and show processes that occur on too large or too slow a scale (from the unfolding of a storm to the replication of DNA), or processes that are occluded by other objects [5, 23–25].

The precise effect that this increasing reliance on visual media over the more traditional mechanism of oral presentation is having on members of a jury, witnesses and other viewers in the court is not currently known. Concerns are beginning to be articulated that the use of computer-generated visualisation technology can distort perceptions, memories, attitudes and decision making in the court. Some research work, previously undertaken in the USA, has examined how members of a jury retain details in their memory from different forms of evidence:

a. Research evidence has also shown that individuals are more likely to be persuaded if the arguments are supported by such visual aids [26, 27].
b. One study showed that the average person retains 87% of information presented visually, but only 10% of information presented orally [28].
c. Another study showed that the average person retains 65% of information presented visually and 15% of that presented orally [29].
d. A further survey showed that individuals will retain twice the amount of information when using a visual presentation, as distinct to an oral presentation [30].

When the evidence is animated, the improvement in memory retention is even more apparent: another survey revealed that members of a jury will retain an increase of 650% of information when presented with presentations using a form of computer animation [31]. The Visual Persuasion Project (New York School of Law) identified a number of issues and problems with the use of visual technology [32]. These issues, along with many others will be expanded upon and addressed later in this paper.

Kassin and Dunn undertook two experiments to assess the effects of computer-animated displays on mock jurors [33, 34]. In both experiments, participants watched a trial involving a dispute over whether a man who fell to his death had accidentally slipped or jumped in a suicide. They observed that when the claimant and defence used an animation to depict their own partisan theories, participants increasingly made judgments that contradicted the physical evidence, suggesting that computer-animated displays can have a greater effect than oral testimony. More recent research by Dunn and others examined the prejudicial effects of computer-generated animations in more detail [35]. This research work offered varying results, depending on the familiarity of the viewers with the scenarios depicted. These experiments also showed that the juror's expectations about the persuasiveness of animations were at odds with the animations' actual influence on jurors' verdicts.

There is little argument regarding the effectiveness of animated visual media as a tool for communication and knowledge transfer. The technology can offer significant

benefits over traditional static (photographic) or moving (film) media captured in the real world. The rendered images from virtual worlds are not bound by the limitations of available lighting; they can avoid extraneous information, focusing only on salient evidential items; and they can be colourful, animated and lively enough to guarantee the attention and engagement of the viewer [24, 36–38].

3 Psychology of Images

Decades of research has shown how fragile human memory can be. Early memory experiments demonstrated how through misinformation and suggestibility we could influence and change the memory of others [39]. More recent work has led to many theories regarding behaviour, and many theories and guidelines are now available to show how human decision making can be influenced by external stimuli [40, 41]. A large volume of research output exists in this field, but the majority of the research work has focused on language and its ability to influence readers and listeners.

There are a number of concerns relating to the viewer's understanding of the visual evidence, based on the issues described above. These are identified and classified below. These are areas of concern that should be considered whenever a visual display or graphical user interface is designed.

3.1 Cognitive Biases

A cognitive bias is a systematic error in thinking that affects the decisions and judgments that people make. Some of these biases are related to memory. The way a person remembers an event may be biased for a number of reasons and that in turn can lead to biased thinking and decision-making. Other cognitive biases might be related to problems with attention. Since attention is a limited resource, people have to be selective about what they pay attention to in the world around them [42].

A cognitive bias is a type of error in thinking that occurs when people are processing and interpreting information in the world around them. The human brain is powerful but subject to limitations. Cognitive biases are often a result of the brain's attempt to simplify information processing. They are rules of thumb that help us make sense of the world and reach decisions with relative speed.

When users are making judgments and decisions about any interactive device or visual image, they like to think that they are objective, logical, and capable of taking in and evaluating all the information that is available. Unfortunately, these biases sometimes lead to poor decisions and bad judgments.

The sheer complexity of the interactive devices around the modern user, the overwhelming bombardment of visual images that surrounds everyone and the enormous amount of information in the environment, mean that users need to sometimes rely on mental shortcuts that allow them to act quickly [43].

Cognitive biases can be caused by a number of different things, but it is these mental shortcuts, known as heuristics, that often play a major contributing role. These biases are not necessarily all bad, however. Psychologists believe that many of these biases

serve an adaptive purpose - they allow us to reach decisions quickly. This can be vital when facing a dangerous or threatening situation [42].

A few of the most relevant cognitive biases are described below:

- '***Framing Effect***': Involves drawing different conclusions from the same information depending on how the information is presented. For example given the following choices:
  - Option **A:** 200 of the 600 people will die
  - Option **B:** 400 of the 600 people will live

  Most people will choose Option **B,** humans choose a benefit over a loss.
- '***Anchoring***': The common human tendency to rely too heavily on the first piece of information presented. For example, a store is selling shoes at $150 and they are not selling. The store then offers them at $500; a week later the store has a sale and discounts the shoes to $200. They will now sell, as the customers were initially '*anchored*' to the $500 price and now only think in relation to that initial figure.
- '***Recognition vs Recall***': Recall is much more difficult than recognition, for example it is easier to recognise a friend than recall their face. When asked the question "*Who wrote the book Moby Dick?*" the answer can be hard to recall. But when asked "*Did Herman Melville write Moby Dick?*" the answer is easy to recognise.
- '***Suggestive Evidence***': The misinformation effect is very powerful, suggestive evidence can influence our memories. In a famous experiment two groups of people were shown the same video of a car accident. When asked what speed the cars **HIT** each other, the average speed was 30 miles per hour. When asked what speed the cars **SMASH** each other, the average speed was 40 miles per hour [20, 39].

The key point is that if we can affect user's memory, behaviour and decision making so much with text and voice information, imagine how much they are affected by visual images and interfaces.

3.2 Memory

Loftus has demonstrated that the memory of a viewer of an event can be biased by a wide variety of seemingly inconsequential factors [44, 45]. The results of Loftus's work can be extrapolated to predict that images and visualisations can possibly to lead to similar biases. Critical variables in how we view such images and interfaces may include the representation of depth, size, shape and colour. The question of how much detail or realism is needed in order for a image of diagram to be effective (i.e. believable) is considered crucial. Object recognition studies have shown that outline drawings can often be just as effective as colour photographs [46], but in other circumstances the interpretation of small details can be critical. Many researcher contend that media displays can occasionally create false memories [5, 7, 12, 37]. Studies have indicated that visual images can create pseudo-memories of an event and the memorability of what was seen can have no validity in fact [47].

3.3 Attitudes

Research has found that when people believe they have a sufficient volume of evidence, they feel more confident about making judgments, even when the information is irrelevant [48]. Images can provide just such an illusion of sufficiency. users are often more comfortable with visuals over oral presentation and discourse, and hence the visuals may be considered more believable. Many factors also influence the credibility of information presented, such as the gender of the presenter, their race, appearance, and socioeconomic circumstances. Visuals visualisation based on information presented have the potential to be more objective and to cause users to discount such factors [49–51]. The anonymous and abstract nature of a well-made visual presentation or interface (one which takes into account the issues discussed later in this paper) may help to remove any such bias or prejudice. On the other hand, a poorly made one may serve to emphasise any such differences.

3.4 Decision Making

Research on group decision making has found that once a group starts a communal discussion, many social and linguistic biases are exhibited, such as group polarisation, production losses and Grice's maxims (which are a way to explain the link between utterances and what is understood from them) [52]. Images can provide a shared memory or representation for users or a group of decision makers. Although this has the potential to reduce a number of social and linguistic biases, it is likely to increase others (for example, production loss). It is necessary to determine if the technology being used undermines critical reasoning; in other words, whether the display that is to be used supports or hinders decision making, and whether it affects the way in which users interact. A reconstruction often contains uncertain or inferred data, which may need to be represented in order for it to be understood by the viewer [53]. The communication and collaborative process between individuals will also be affected by the type and extent of the display and will also determine content, in as much as it might affect the way groups reach decisions [54, 55].

4 Recommendations for the Use of Evidential Images

The previous sections have described how information presented using computer generated visuals can be extremely advantageous, providing they are used appropriately. However, potential difficulties can occur from the use of this technology, and when the use of these images are examined in further detail, a number of issues and questions can arise. In a courtroom setting, the consequences of these problems cannot be underestimated, since errors, inaccuracies, misuse, tampering or bias within visual and graphical evidence are capable of leading to miscarriages of justice.

On reflection, many of the issues regarding the use of technology to generate explanatory visuals and graphical interfaces can be expressed as a list of advantages and disadvantages, as shown in Table 1.

Table 1. Advantages and disadvantages of using evidentiary visuals.

Advantages	Disadvantages
Such displays can provide an effective means of conveying complex evidence to the user. Visual memory has been found to be highly detailed and almost limitless, in contrast with memory for verbal material [56]. Images and diagrams have the potential to improve a viewer's ability to retain complex spatial and temporal data and hence increase the potential comprehension of complex information	The very fact that images and visuals impress themselves on the memory, and are persuasive and convincing, is also their greatest disadvantage: they can leave a strong impression on viewers. Moving images tend to mesmerize, and they can relax an individual's natural critical nature. This means that viewers are inclined towards a 'seeing is believing' attitude, as they do with television, potentially reducing the standards expected when critically assessing the information [20, 61]. Simulations can assume a 'hyper-real' character that eclipses the significance of the reality [62–64]
Visual media can provide an increase in the attention span of the viewer, since human attention is naturally drawn to animated images. Moving objects rank top on the hierarchy of methods to draw attention, which covers actions, objects, pictures, diagrams, the written word, and the spoken word [57]. A modern audience will more readily engage with audio-visual forms of communication, rather than relying solely on verbal modes of discourse	It is often difficult to represent uncertainty in images. Viewers often wrongly believe there is little or no margin of error in information presented in a visual form [53, 65]. Research studies have examined how to visualise uncertainty and provide non-prejudicial representations of uncertain information [5, 24, 53]
Computer displays can also act to help persuade users and inspire confidence. Studies comparing oral, textual, and static visual presentations to computer-generated animated presentations containing the same information found the animations to be more memorable [28–31]. This has implications not only for the retention of information, but also the weight given to the information viewed by the user [5, 58]. Also, visual, rather than verbal information, more readily activates the formation of an impression [59]	The flexibility of a computer-generated image also implies that they inherently contain the potential for tampering and alteration. Image quality does not equate with sufficiency, and the public's general knowledge that filmmakers can use computers to resurrect dinosaurs and create alien landscapes make allegations of digital alteration a potentially major issue when it comes to the weight placed on visual information [66]. The image creator must also be able to prove the accuracy of their reconstruction, both with reference to the original data, and to validate the development stages of the image itself [24]
Interactive displays also have the ability to provide the creator with an improved illustration of their arguments; the user can retrieve information instantly, and the display can be manipulated for better viewing. The user can zoom into an area of interest, examine a specific piece of information in more depth or create overviews of the whole display [24]	A party may intentionally create an image or virtual reconstruction that provides a favourable perspective to support a particular hypothesis, or unintentionally choose a viewpoint, perspective, illumination model or colour scheme that alters the appearance of the image or animation to work against the same hypothesis. This could create bias in the viewer, whether that is conscious bias (a form of tampering) or subconscious bias [34]. Designers and the creators of virtual reconstructions can learn much from the work of film and media theorists who continually strive to define the nature and functions of the media in which they work, particularly in relation to viewer perception and engagement [13, 67]
Increasing using of graphics and visuals can improve the efficiency of displays, thus time, as arguments and complex information are understood at a faster pace. The increase in efficiency because of the use of graphical display technology is a factor of the potential improvements in the speed with which complex information can be imparted to an audience, which therefore may shorten the length of a task [17, 60]	

A number of these potential issues along with recommendations to overcome them are discussed below. By their very nature, any recommendations and guidelines formulated are likely to be broadly defined and generic. Many of the recommendations offered below are little more than general suggestions that users of the technology be aware of these issues when involved in developing the types of images and reconstructions to be

used in critical situations such as courtrooms [68]. Unfortunately, many of these recommendations have been ignored in the past when such technology has been used, and this may have been a contributing factor to the admissibility problems encountered when using this technology in certain jurisdictions [2].

4.1 Viewpoint (Field of View)

One issue with images used in courtrooms is how to correlate the viewpoint of a witness in a 'virtual' environment with the view from their physical position at the scene. For example, compare the problem of accurately replicating the 'physical world' view of the driver of the vehicle involved in a road traffic accident with the field of view of a camera in a virtual reconstruction. The driver has a wide field of vision through two eyes with differing levels of visual acuity across the field of view (for example there will be lower resolution vision at the periphery of the field of view compared to the current focus of attention), and the driver may also move their head around within the car to gain a better view. Whereas, animated driving simulations often rely on a fixed camera viewpoint within the vehicle [69].

Popular computer game titles provide a good example of distinct viewing configurations through various playing styles. Unreal Tournament (Epic Games) and the Halo Series (Bungee Studios) are examples that belong to a genre known as the First Person Shooter (FPS); distinguished by a first person perspective (egocentric) that renders the game world from the visual perspective of the player character. Grand Theft Auto (Rockstar Games) and Tomb Raider (Core Design) are games that belong to a genre known as the Third Person Shooter (TPS); this is a genre of video game in which an avatar of the player character is seen at a distance from a number of different possible perspective angles (exocentric). In any forensic reconstruction (as in any computer game), the choice of the viewing perspective may have significant effect on the way an image is interpreted by the viewer. Changing the viewing perspective can potentially alter which 'character' in an evidence presentation a viewer identifies with, or aligns themselves with [5, 22, 70].

However, research has shown that in positioning the virtual camera to represent a specific subject's viewpoint can actually incline the viewer to attribute less responsibility to the actor whose point of view the simulation leads them to adopt and more responsibility to other actors or to the circumstances. Cognitive psychologists call this actor-observer bias, and it is a bias since this point of view ought to be irrelevant to judgements of responsibility. This actor-observer effect is well established in the social psychology literature [71].

Designers of images, interfaces and reconstructions ought to study film-making techniques for two reasons. First, to be able to achieve the same effects as a film-maker; perhaps getting the viewer to identify emotively with a particular character in a reconstruction to enhance the power of the message. More importantly, a designer may wish to eliminate these effects and to remove the emotive content to provide an objective, understandable view of a forensic data set, with no distracting emotive attachment. An awareness of the ways in which the viewer can be manipulated (for example, through the use of egocentric and exocentric viewpoints) is essential [5, 20].

4.2 Realism and Level of Abstraction

The environment surrounding any particular scene that is to be reconstructed may be included within image presented in court. For example, a model may not only show the location of items or objects that form part of the evidence, but also the position of such items in relation to nearby buildings or other environment features, and these items may be placed and animated within a chronology of events or a time frame.

The realism of 'virtual' environments continues to improve. A number of researchers have noted an interesting observable fact relating to the realism in animated imagery, where many viewers become 'unnerved' by images of humans which are close to, but not quite real. This phenomenon has become known as the 'uncanny valley', because of the sharp dip seen in a graph of familiarity against the perception of reality [72]. As computer-processing power increases and software tools develop, it is natural to assume that it will be possible to achieve a similar level of realism to that used in photorealistic animated Hollywood movies within the computer-generated images used in courtrooms and other environments where critical decisions are made.

Virtual objects in a court reconstruction can be modeled with varying degrees of accuracy to explain and visualise the certainty, believability and veracity of the information related to that object. For example, trajectories of bullets are often displayed as cones or wedges within shooting reconstructions to show a range of possible positions of the weapon, instead of showing a single definitive line trajectory [53].

However, the mixing of visual metaphors and modes may be potentially disorientating to some viewers. Combining abstract data representations in photo-realistic environments may provide an unnatural experience for the viewer. Fielder has commented on the way members of juries may be misled by the use of visual metaphors and abstract representations in forensic animations. Combining different degrees of photorealism and expecting the viewer to draw additional information from a number of abstract representations in the virtual environment may overload the viewer and potentially add to their confusion, rather than increasing their comprehension of the evidence that is presented. In a forensic graphics context, many presentations used in court currently rely on fairly abstract representations [38]. However, as technology develops, the development of increasingly photorealistic evidence reconstructions becomes ever more likely. Increasing use of the rendering of photorealistic components into images may lead to instances where viewers may be lulled into a 'seeing is believing' attitude, causing a potential relaxation of their critical faculties [48, 73, 74].

Hence, careful use of visual metaphors is essential. Thought needs to be given to each abstract data representation in the environment and how that will be perceived by the potential audience. Experience and literature from disciplines such as psychology, cultural and critical theory, visual media, art history, education and such like can inform how abstract (and realist) representations are interpreted by the viewer. This in turn provides for what the viewer remembers and understands from the images presented to them [5, 11, 43]. An example of a realism issue is shown in Fig. 2.

Fig. 2. A photo from a murder scene is on the left, a computer-generated image is on the right.

4.3 Media Mode

It is rare that one form of media will be sufficient to explain fully every facet of a complex process or case to a viewer. It is important to choose an appropriate representation mode (photographs, text, video, graphics etc.) for the information that needs to be presented. Additional data may be included and displayed within any virtual environment; for example, location based statistical or analytical data may be displayed, calculation and test results may be presented in a visual format, and original documents and photographs can be linked to three-dimensional virtual objects.

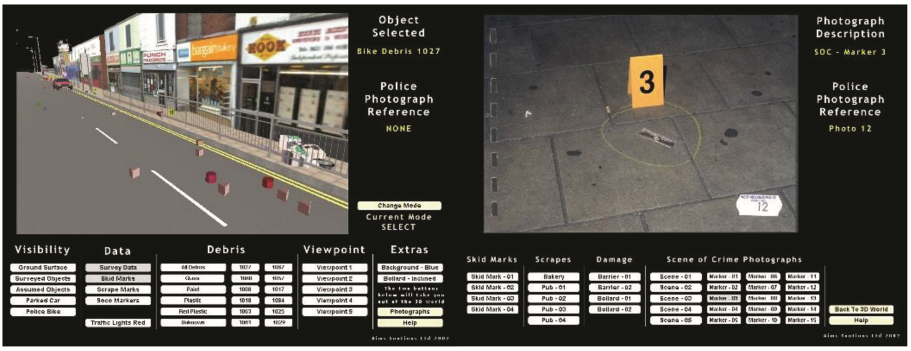

Fig. 3. A real time evidence display system (a murder trial) showing virtual and real imagery.

A reconstruction developed for the West Midlands Police in the United Kingdom (by the author) uses real-time virtual reality technology (Fig. 3). The user can pass the mouse over any relevant piece of evidence and view textual data about that item, and by clicking on any particular object in the virtual world (in this case, mainly items of vehicle debris), relevant crime scene photographs and evidential data will be displayed. The linking of 'real' evidence to spatially contextualised hotspots in a virtual environment has the potential to provide an effective mechanism to help the viewer understand

the spatial relationship of the evidence. Such a multi-modal approach can be very effective, and different media may also be used as a device to help to retain the attention of the viewer and thereby increase understanding [22, 24].

It is important to be aware of the effect that the particular form of media being displayed will have on the viewers, and also to have an appreciation of the context in which it will be experienced by the user. The pedagogical effect of transitions between the forms of media should be considered. For example, switching between a virtual, rendered image of a crime scene and a real crime scene photograph may cause confusion in the viewer as they attempt to correlate evidence between the different forms of media [11, 20, 24].

4.4 Resolution

One difficulty is to correlate the resolution of an image with that subjectively perceived by the viewer in the physical world. In this instance, resolution not only refers to screen image dimensions (the pixel count), but also to the level of photorealism of the virtual environment that is created [5]. This also relates to the display mechanisms used: viewing an image on a mobile device such as a mobile telephone or an iPod is a very different experience to watching it on a cinema screen. In addition, seeing an image or animation on a screen may not have the same experience (depth of field, motion parallax, peripheral vision etc.) as a viewer watching the actual event [75, 76].

Careful thought needs to be given to the enabling technology; it is necessary to consider how the user will interact with any visualisations created. For example, the best mechanism for a particular case may be to deliver a spatially contextualised evidence visualisation to a user's personal device (a mobile telephone or iPod screen) as they traverse the actual scene. Alternatively, a complex forensic data set with many spatially interlinked evidential items may be best utilised as a shared viewing experience on a large screen in the court [5, 20, 24].

4.5 Audio

The integration of physical-world audio evidence with a forensic animation has been used in the United States for many years. One of the first recorded applications of such a forensic animation was the reconstruction of the Delta 191 airplane crash in 1985 [77, 78]. In the court, the animated evidence showing the movement of the airplane was played simultaneously with an audio recording from the cockpit voice recorder. Research suggests that adding audio to a computer-generated visual can have a significant effect on the level of engagement of the viewer, and hence may potentially affect their understanding and interpretation of the evidence viewed [79].

The integration of sound into the virtual world is often overlooked or added as an afterthought. Very few designers or developers are also qualified as or competent at being sound engineers. Effective audio soundtracks can add new dimensions to the viewer's media experience. The addition of an audio track can be a positive alteration to the visuals, providing an increased understanding of events or it can be distracting, adding unnecessary emotional context [5, 79].

4.6 Accuracy

If the images and virtual reconstructions are created to a sufficient level of accuracy, then they may potentially be used to test hypotheses in a courtroom. Examples include verifying the location of a witness (especially where lines of sight around obstructions or hazards that are present in the environment may call into question the physical location of the witness) or perhaps to evaluate potential alternative bullet trajectories through the environment [80].

The use of generic computer models allows the recreation of dynamic events. Such reconstructions are, by their very nature, often dependent on the knowledge, expertise and opinion of experts [81]. Hence, in many of these cases, the advice of the expert is seen as crucial in creating a graphical representation that accurately matches the medical opinion. However, the potential inaccuracies involved mean that these reconstructions must be viewed cautiously and the uncertainty associated with the exact position of virtual objects must be explained to the viewer [82].

4.7 Simulation

It should never be forgotten that most computer-generated visuals are by their very definition a simulation of reality. In the context of the courtroom, it is necessary to understand the nature of the simulation and the veracity of the representation - that is how close it is to the original evidence from which it was derived.

However, questions that arise include whether visual applies scientific theory in the same way as the expert; whether the simulation works to the same level of accuracy; whether the simulation makes the same assumptions as the expert; and whether the visual representation provides a realistic portrayal of the simulation data [8, 69].

It is important that the developers of these images have an understanding of the processes and events being simulated (whether this is vehicle movement, bullet trajectories or human anatomy). The developers must be aware of the veracity and realism of the simulation - that is, the accuracy of the model. Also, it is important that if decisions are to be made based on the images created, then it is necessary that information is made available that explains how the simulation works and details of the underlying mathematical model [5, 24, 69].

4.8 Narrative

The ability to move through time and along a chronology of events in the virtual environment may be potentially disorientating to many viewers. Most are used to linear narratives (such as those in books or films), and may struggle to follow multiple narrative threads when faced with such a non-linear approach [83].

In an interactive simulation, the user may often take control of the narrative, altering the chronological presentation of information, and choosing which information they see at which time. This can easily become confusing to the viewer, particularly to those used to linear narratives in other media (for example, novels and films). Developers should produce a guide to the interactions in their environments and be aware (through user

testing) of how the users are able to interact with the data and any possible unexpected interpretations that may result [24, 83].

5 Empirical Evidence of Effects

Australia currently has a number of projects underway in this thematic area. In Western Australia, rare permission has been given by the Attorney General for a researcher to interview jurors after criminal trials in which a range of expert evidence was presented. While the data showed statistically significant findings that jurors are clearly influenced in their treatment of some forensic evidence by the manner of presentation, reassuringly, no support was found for the operation of a detrimental effect of the technology. In fact the study found support for the proposition that most jurors assess forensic evidence in a balanced and thoughtful manner, whatever the mode of presentation [84, 85].

Fig. 4. Computer-generated graphical images from the JIVE terrorism trial.

The author was a member of a large international research project based in Australia, the Juries and Visual Evidence Project (JIVE), which also examined some of these issues. The project measured the effect of interactive displays on the trial process; specifically whether forensic animation and virtual reconstruction technology better informs juries or potentially increases prejudice against defendants [86].

In January 2008, the JIVE project team ran a number of mock trials in the Supreme Court in Sydney, Australia. A range of forensic animations and interactive

reconstructions of evidence relating to a terrorist bombing were shown to a number of different groups of jurors (Fig. 4).

Each jury deliberation was filmed and recorded. A major theme emerging from the analysis of the project data is that the main experimental effects (interactive visual evidence and judicial instructions) have relatively modest influence overall. However, they do show stronger effects in some groups of people, particularly those who are most prone to convict. The JIVE data has so far shown that fear of terrorism may be a better predictor of a verdict than either the method of presentation, experimental interventions, deliberation or any demographic characteristics. The research team intends to publish a book on the data from this project which will focus on issues of juries and trials in terrorism cases [22, 24, 86].

6 Conclusions

In many courtrooms, the crux of any case is the presentation of information to the finder of fact, whether in the form of an opening statement, evidence or closing argument. The need for a clear presentation is summed up by Burns, who states [87]:

> *'The presentation typically takes the form of a report, and the scientist must be prepared to explain this report in such a way that a typically science-phobic judge and jury are able to comprehend it. Presentation is everything.'*

The unavoidable future for courtrooms across the world is the introduction of technology; this technology could be merely electronic filing and teleconferencing, but is likely to encompass many forms of computer-generated imagery. As computer-graphics based technologies continue to evolve, this will inevitably lead to improvements in the realism of evidential graphics and virtual simulations. This could, in turn, result in jurors and triers of fact experiencing a greater depth of immersion when viewing and experiencing the incident within a virtual world. This could also potentially lead to a corresponding increase in their acceptance or belief in the hypotheses being presented; and conversely also result in a rise in any associated possible prejudice caused by the visual media.

In conclusion, designers should endeavour to ensure that any images produced accurately reflects the scientific data available and augment the testimony of the witnesses. However, to be effective, the evidence must not only tell 'the story' but also be understood easily. To that end, designers must strive continuously to develop new and creative ways to present complex information. Graphics based technologies have the potential to have an important effect on many future cases.

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