Perception of Movement and Orientation in Digital Medical Imaging

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ABSTRACT

This paper presents preliminary results on an investigation into a visual illusion observed in health care. The illusion is demonstrated in radiological imaging and may have implications for patient safety. A URL to a video of a Positron Emission Tomography (PET) scan image was circulated and participants reported the type of movement they observed in the video. There is a wide variation with respect to the observations reported, which appears to be independent of gender or age differences. The clinical significance of this finding is discussed and plans for further investigation of the phenomenon are outlined.

Categories and Subject Descriptors

H.5.1 [**Information Interfaces and Presentation**]: Multimedia Information Systems—*video*; I.2.10 [**Vision and Scene Understanding**]: Perceptual reasoning—*Perceptual reasoning*; K.4.3 [**Organizational Impacts**]: Computer Supported Collaborative Work

General Terms

Human factors

Keywords

Computer-Mediated Visual Perception

1. INTRODUCTION

Patient imaging is often considered to be at the heart of the health care system. There have been extraordinary advances in medical imaging in recent years, both with respect to the range of modalities used, such as x-rays, electromagnetic fields, ultrasound, radioisotopes, and the computational power facilitated by digital imaging. Increasingly, routine hospital work has come to rely on sophisticated digital imaging systems to display computer-enhanced images that allow for accurate representation of anatomical structures. Advances in imaging technology are facilitating the development of new specialisms such as the field of intervention radiology and are also making it easier for needle sampling of lesions for pathology, under vision, that previously were only accessible via surgical procedure. Developments in other medical sciences too such as radiation therapy, orthopaedics and robotic surgery are all highly dependant on accurate visualisation, measurement and volume assessment in image data. Radiological imaging today can reproduce structural location, textural and functional data, and the precision which can be achieved is constantly being refined.

Image processing tools aim to generate and manipulate images that enhance the information content for assessment. How people perceive and interact with a visualisation tool can strongly influence their understanding of the image data. Accuracy of diagnosis, and ultimately the efficacy of diagnostic radiology, depends on the conditions under which patient images are viewed [2]. The interpretation of medical images, mediated by computer, is an area that has been gaining attention but remains to be fully explored with respect to human-computer interaction (HCI) [19]. There has been growing recognition that more attention should be paid to users who must view and manipulate the data, because how humans perceive, think about and interact with images will affect their understanding of information presented visually. The strong need to study human factors as a basis for medical visualisation design is further emphasised by the rapid advances in graphics hardware devices for 3D visualisation in this field [10]. It is critical that any HCI issues that may influence the interpretation of image data must be fully understood and measures put in place to minimise any detrimental effects introduced by the system, or tool.

This paper reports on a video image interpretation exercise conducted with a number of volunteers. It is the first exercise in a series of tests to be conducted on PET videos that aims to investigate if the illusion demonstrated might be associated with an increase in 'side-marking' errors in medicine. The PET video scan used in the exercise is available on the Internet and is similar to that viewed in day-today hospital work.

2. BACKGROUND

Radiological information takes many forms, including the spatial distributions of acoustic impedance, attenuation coefficients, proton densities and radiopharmaceutical concentrations [15]. These technological advances can produce high resolution imaging, but the success of medical imaging de-

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pends on a subjective notion of image quality that is often difficult to define and on factors that influence observers' ability to interpret the information [15]. These factors are both i) image dependent, i.e. relating to visual conspicuity of relevant features, and ii) independent of the image, i.e. cognitive in nature and relate to what the observer knows about the visual information. However, despite all the technical innovation and our knowledge of peoples' perception and anatomical structures, the issue of a patient's orientation, or laterality, is usually determined through non-technical procedural methods [13].

The importance of correct interpretation of laterality in medical imaging is a recognised pitfall in diagnostic radiology, with potential for a wrong-side procedure being undertaken with serious consequences for the patient. Although the reported incidence of adverse events being directly attributable to incorrect marking of the body site on the radiological image is relatively small [18], cases are reported where either the marker has been misplaced or omitted [1, 4].

In the days of x-ray film radiology, a common error was to view the film from back to front on a viewing box. The advent of picture archive and communication systems (PACS) has improved efficacy in radiology, and 'wrong side viewing' is virtually extinguished because nowadays soft copy images are viewed on high resolution computer monitors. Although reviewing patient images on high-resolution monitors eliminates the problem of wrong side viewing, other issues may be introduced that need to be examined which relate to viewing electronic images.

Volume rendering of three dimensional shape and structure in translucent media, often combining several modalities poses challenges to visualisation of medical images due to both work practice (e.g. user training based on analysing 2D images) and perceptual factors (e.g. the potential for ambiguities) [12]. Furthermore, the issue of patient image laterality often relies on anatomic cues, which sometimes can be difficult to determine accurately in disease. In PET scans, for example, there are no left vs. right markers in the common video formats in widespread use, and laterality is regulated through non-technical procedures. Efforts are being made, however, to automatically check patient orientation in scan image data [6].

A perceptual ambiguity issue which might affect interpretation of PET images presented on video is related to the popular *spinning dancer* illusion, created by Nobuyuki Kayahara [11]. The spinning dancer is a kinetic, bistable optical illusion[1]. These kind of illusion is considered to result from the lack of depth cues in the image and are considered to be generally confined to silhouette figures. In the PET scan video, transparency, occlusion and other features [20] are thought to provide some depth cues as the figure rotates, and even non-medically trained participants can presumably use the anatomical cues to help them in their interpretation of the figure's orientation. We tested this assumption in the experiment described below.

[1]It has been widely reported that people see movement both ways in the spinning dancer figure. At one stage this was associated with erroneous claims about right and left brain hemispheres, and even identified as a "personality test" [3].

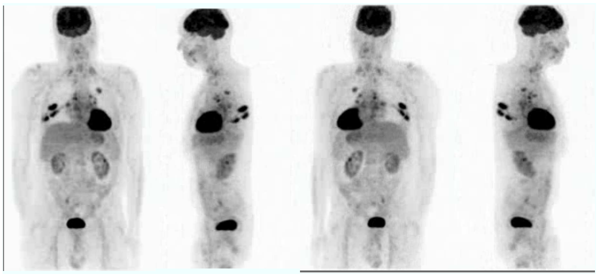

Figure 1: Images from PET scan video. Depending on one's perception, the figure appears to be turning clockwise, anti-clockwise, or in both directions.

3. METHOD

A web address, `http://www.adronline.org/html2/pet_vid.htm`, displaying a video of a PET scan (Figure 1) was circulated to a group of academics and students on the Department of Computer Science mailing list, and to a number of hospital clinicians known to the researchers. Participants were invited to participate in the study and to advise the researchers if the image appeared to be moving or stationary. If moving, participants were asked if the image is rotating clockwise (to his right), or anti-clockwise (to his left), or in both directions. If moving alternately in both directions, they were asked if one or other direction is predominant. Participants were asked to submit their gender, their preference to use their left or right hand and and their general age group, i.e. under 30, between 30 - 40, or over 40 years of age. Occupation was noted whenever possible. Responses were returned via email. The participant profile is given in Table 1.

4. RESULTS

A total of 368 responses were returned from a circulation list of approximately 800 addresses. Results are given in Table 2.

Table 1: Participant profile (%)

Gender			
Male	Female		No Ans.
198 (53.8%)	168 (45.7%)		2 (0.5%)
Handedness			
Right	Left	Ambid.	No Ans.
309 (84%)	43 (12%)	8 (2%)	8 (2%)
Age group			
< 30	30 - 40	> 40	No Ans.
162 (44.1%)	122 (33.2%)	82 (22.4%)	1 (0.3%)

The exercise was simple to conduct. Participants reported that the exercise was 'fun' to do and it was easy to report results in an email reply as requested. No forms were involved. Several participants submitted comments on their experience when undertaking the test. These comments provided further insight into the difficulties experienced in assessing the orientation of the figure. Results were entered into a statistical package and analysed using non-parametric tests. Chi Square tests were conducted as well as Pearson's, and Spearman rank correlations.

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Table 2: Reported movement of PET scan video

Movement	Frequency	%
Clockwise	148	40.2
Anti-Clockwise	42	11.4
Both directions - Equally	51	13.9
Both directions, Clockwise dominant	76	20.7
Both directions, Anti-Clockwise dominant	50	13.6
Stationary	1	0.5
Total	368	100

Responses to the question on movement for gender, handedness is given in Table 3. The reported movement in the PET scan video appears to be independent of age or gender. Right handed subjects report more clockwise movement and left handed subjects tend to report more anti-clockwise movement, 62.2% vs. 60.5% and 30.2% vs. 25% respectively. Pearsons Correlation $r = 102$, $p = .050$, Chi Sq. $\chi = 0.43$.

5. DISCUSSION

Visual illusions in computer-mediated environments, including radiological imaging (Mach bands), have been reported in literature. The findings in this PET scan video exercise suggests that PET videos induce visual illusions related to the absence of depth cues. Depending on the observer's perception, the direction of spin may change a number of times.

In this test, observers reported a wide variation in movement, and in the direction of movement (Table 2) and one observer reported a stationary figure. Subjects were not restricted in their time looking at the video and many reported that the longer they looked, the were more likely to see variation. Others reported if they looked quickly away and back again that they could see movement in the opposite direction. The prevalence of this visual illusion in medical work is unclear. However, since PET scan videos do not normally have a laterality marker, it can be assumed that ambiguity is common for people reviewing such scan images. Our difficulty in identifying such illusions is that for any individual assessing the image, it is difficult to imagine that other individuals do not see it in the same way. It is disconcerting when a group reviews such a PET scan video, in a forum such as a team meeting, and find that they are at variance as to how to interpret the patient's orientation [9].

It is at first surprising that this visual illusion believed to be accounted for by the *lack* of depth cues, is sustained in the PET scan video, that demonstrates internal anatomic structures, partial occlusion, semi-transparency and other features one would expect to provide depth cues. However, the lack of shadows, shading, perspective and texture gradients may account for the difficulty in perceiving depth in the figure, as these features have been shown to allow perception of opaque volumetric objects [19, 8].

Observers sounded puzzled when reporting their observations. One observer reported that "... depending on which part of the body I focus on the direction of rotation appears to change". Another noted that "without the heart as a reference point it can appear to be going either way". One non-medical observer reported that "If I focus on the body it seems that he oscillates from one side to the other, always facing forward ... even though the heart changes sides ...". Another reported: "(he) seems to rotate from one side to the other and back, always facing me", while another said he moves "from right to left and back again". This apparent oscillation has been recorded in the hollow mask illusion, another class of bistable illusion that is associated with a bias to perceive convexity in a face [7].

That such variation in observation should be reported is a cause of concern and warrants further investigation. Given that many errors in medicine can be attributable to miscommunication of information, and the central role of radiological imaging in medical work, it is a natural question to ask if such visual illusions may be underlying some mislabelling of patient laterality [14] and contribute to errors.

Just as Mach bands do not exist in the real sense but are perceived as real by the visual system, the interpretation of the figure rotation is real for the observer. The visualisation of Mach bands depends on a set of variables that primarily involve the contour and optical density of a structure at an interface relative to that of its surround [5]. Despite Mach bands being an illusion, or artefact, they are documented both as a source of error to the inexperienced observer [17] and as a useful aid to the experienced. Mach bands can help differentiate normal from abnormal anatomy and thus increase diagnostic yield [5]. Chasen (2001) explains that Mach band visualisation can contribute to a greater understanding of 3-dimensional structures projected onto 2-dimensional radiographic film and can prove helpful. However, with this PET video illusion, it is difficult to imagine how it might be used for benefit. It is more likely that it will be shown to be a pitfall in reporting.

The potential for technological interventions to provide an automatic laterality marker and reducing the error incidence is often overlooked. Effort for computer-assisted visual feedback to improve the perception of medical images is on-going and Nodine et al [16] explain that diagnostic interpretation in radiology is prone to error primarily because "the perceptual system evolved to perceive real-world objects, not images of them" [16]. As an effort to improve observers' perception of image data, efforts to automatically detect patient orientation and reduce the incidence of wrong-side treatment errors [6] are being developed. Simulated cues of stereopsis, the perception of depth due to difference in right and left retinal images, and aerial perspectives, modelled by decreasing contrast as distance from the viewer increases, are also being investigated to provide better depth perception in computer generated images [12].

The clinical significance, or relevance of this finding, has not yet been determined. It has been observed on occasion that clinicians appear to have some difficulty in interpreting patient laterality in PET scan video images [9], which may be related to this illusion demonstrated here. While reference to anatomical structures in the normal body provide cues for medical staff, patients with tumours or abnormalities can be anticipated to cause confusion.

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Table 3: Frequency in Observations by Gender and Handedness (%)

	Still	Clockwise	Anti-Clockwise	Moves in Both Directions Equally	Clockwise dominates	Anti-Clockwise dominates
Gender						
Male	-	85 (42.9)	24 (12)	27 (13.6)	41 (20.7)	21 (10.6)
Female	1 (.6)	62 (36.9)	18 (10.7)	23 (13.7)	35 (20.8)	29 (17.3)
Handedness						
Right	1 (0.3)	130 (42)	37 (12)	39 (12.6)	62 (20.1)	40 (13)
Left	-	15 (34.9)	5 (11.6)	4 (9.3)	11 (25.6)	8 (18.6)
Ambidextrous	-	-	-	5 (62.5)	2 (25)	1 (12.5)

5.1 Future work

While this exercise had demonstrated clearly that the PET scan video is visualised by people differently, this does not demonstrate that there are clinical implications in this visual illusion. The next step in the project will examine if people's perception of the image facing or turned away is different, and affects their ability to label the left or right side of the figure. It also remains to be demonstrated if there is a correlation between peoples perception of the direction of movement and their propensity to see the image facing or turned away.

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