A Study Of Contrast-Detail Detectability of Computer-Generated Test Objects

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Citation

M Nizam, K Ng, B Abdullah. *A Study Of Contrast-Detail Detectability of Computer-Generated Test Objects*. The Internet Journal of Radiology. 2001 Volume 16 Number 1.

Abstract

Contrast and size are among the several factors that influence human perception in visualization of radiographic images. In this study, 25 circles were generated in random positions using a random number generator on a black background on a Sony GDM-500PS monitor (1280x1204 matrix at 85 Hz). Each circle has a combination of different shades of grey (19%, 26%, 37%, 51% and 72%) and diameter (1.00 mm, 1.41 mm, 2.00 mm, 2.83 mm and 4.00 mm). 10 images were generated and displayed to 10 observers for evaluation. Observers were asked to record the number of circles they can detect for each circle's size in each image and the answers are given scores. The mean from the biggest to the smallest circles are 1, 0.974, 0.932, 0.864, and 0.772 respectively. This indicates detectability decreases with object size.

All work was done in the Department of Radiology, University of Malaya Medical Centre, Kuala Lumpur, Malaysia.

INTRODUCTION

The introduction of digital radiography and Picture Archiving and Communication Systems (PACS) raise concerns about the confidence of lesion detectability from a digital display [1]. The stage of reading and interpretation of radiographic images is vital to the constant effort to improve the physical means utilized to perform the most crucial step in the radiological imaging chain. Viewer performance is affected not only by the quality of display devices but also the viewing conditions environment such as spatial and contrast resolution of the display device, brightness and the displayed luminance range of the monitor and extraneous light in the reading room [2].

In this study, a set of contrast-detail objects in random positions were used to investigate the relationship between size and contrast of an object and detectability when viewed on a colour cathode ray tube (CRT) monitor. The objects are generated according to the Rose model that describes the signal-to-noise ratio needed to observe an object of specific size and contrast [3, 4]. The room ambient light and the display brightness were fixed to simulate a normal radiographic reading room.

MATERIALS AND METHODS

A program based on Microsoft Visual Basic 6.0 software was used to generate an image of 25 circles on a black background across a 1280x1024 matrix display monitor. The circles were combination of different shades of grey which were 19%, 26%, 37%, 51% and 72% brighter compared to the black background and of different diameters which were 1.00mm, 1.41 mm, 2.00 mm, 2.83 mm and 4.00 mm. A set of 5 circles with different sizes as mentioned and all with a 72% contrast were also included at the left of the display as reference. None of the 25 circles was allowed to generate in the reference area. The luminance contrast, C, of the shades of grey is derived from:

Figure 1

$$C = \frac{L - L_0}{L_0}$$

where L is the luminance of the circle and L0 is the luminance of the background [5]. All luminance measurements were taken using a luminance level meter, Mavo-Monitor (Gossen-Metrawatt Gmbh, Nürnberg, Germany).

Each time the program is run, by using a random number generator, the circles generated were in random non-overlapping position across the display monitor. A total of 10 images were generated on a Sony GDM-500PS monitor with an 85 Hz flicker rate and captured in bitmap format. The captured images were then displayed on the same monitor to 10 observers who were asked to record the number of circles they can detect for each circle's size in each image.

Figure 2

Figure 1: A sample test image showing randomly generated objects of various sizes and contrast levels.

The mean luminance of the display monitor on the black background was fixed at 3.02 0.05 cd/m2; measurements were taken from the four corners and the centre of the display. The room illuminance level was fixed at 5.0 0.1 lux; taken at a distance of 50 cm parallel to the centre of the display monitor using a photo-meter (Quantum Instruments Inc., model PMLX, New York, USA). Table 1 below gives the scoring system used in this detectability study. These score represents the detectability of the circles according to their sizes for each observer.

Figure 3

Table 1: Scoring system used for the detectability study.

Number of circles counted	Score
5	1
4 or 6	0.8
3 or 7	0.6
2 or 8	0.4
1 or 9	0.2
0 or 10	0

RESULTS

The means of points or detectability from the 10 observers according to circle's sizes from 4.00 mm to 1.00 mm were 1, 0.974, 0.932, 0.864 and 0.772 with percentage standard deviations of 0, 1.8, 3.4, 3.4 and 9.1 respectively.

The results for each image from the 10 observers as can be seen from Table 2 and Figure 2 show an overall degradation in detectability as the circle's size became smaller. Detectability for the smallest size (1.00 mm) circles varies considerably among different observers. This degradation of detectability trend is more visible if the mean for the 10 observers were plotted against circle's sizes as shown in Figure 3 with the error bar becoming larger as the size decreases.

Figure 4

Table 2: Percentage of detectability of 10 observers.

Diameter (mm)	4.00	2.83	2.00	1.41	1.00
Image 1	100	98	94	92	70
Image 2	100	98	94	86	70
Image 3	100	96	84	84	68
Image 4	100	98	92	92	80
Image 5	100	100	96	86	82
Image 6	100	96	92	82	60
Image 7	100	94	94	84	82
Image 8	100	100	96	84	84
Image 9	100	98	92	84	90
Image 10	100	96	98	90	86

Figure 5

Figure 2: Percentage of detectability of 10 observers plotted against circle's diameters for each test image.

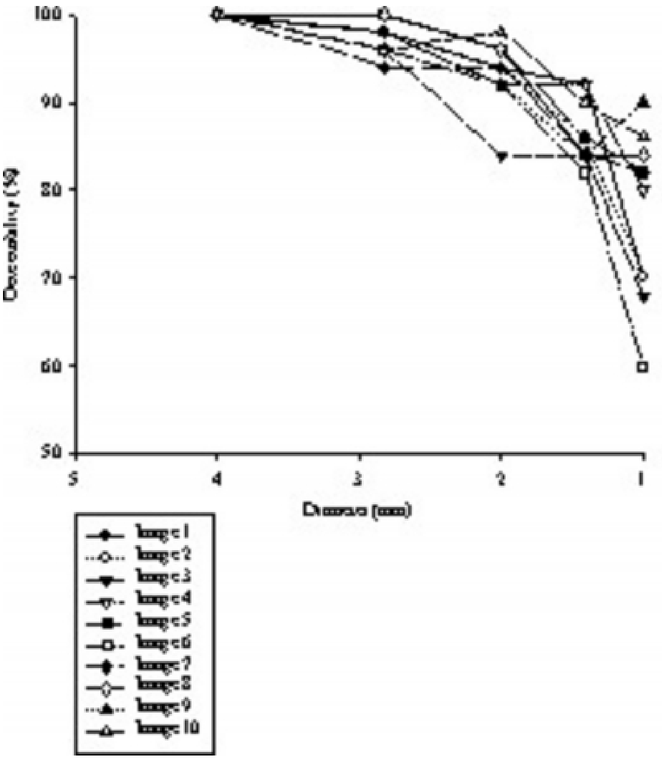
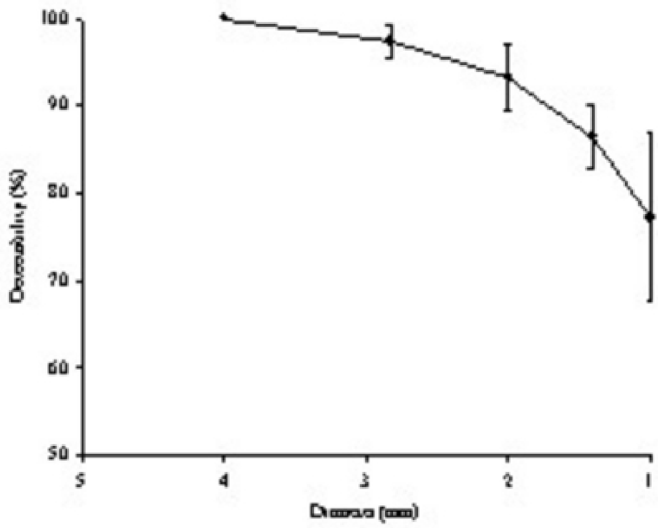


Figure 6

Figure 3: Overall percentage of detectability of 10 observers with error bars plotted against circle's diameters.



DISCUSSION

Overall the detectability of the test objects degrade but as can be seen in Figure 2, the degradation is inconsistent for size below 2.85 mm and the error bar for detectability of size 2.00 and 1.41 mm are almost the same. This may indicate the observers have difficulties in differentiating or detecting the smaller sizes and rely more on guesswork. However the method stated in this study does not allow for such direct assessment to be made.

Although the randomness of the test objects positions provides an unbiased observer evaluation, a better method of assessment and scoring is needed to assess detectability specifying size and contrast. It is also evident that future study should emphasize object size of below 2.85 mm.

CONCLUSION

This work demonstrated that detectability is affected by size and contrast of the object viewed on colour CRT monitor. Generally, a smaller low-contrast object is less visible. However an object has to exceed visual physiological thresholds both in size and contrast to be seen and each observer has different thresholds. In digital images, this would relate to spatial and contrast resolution of the display device, brightness and the displayed luminance range of the monitor and uniformity of the display system luminance.

ACKNOWLEDGEMENTS

The authors would like to thank Dr. David Dowsett from Dublin, Ireland for his support and useful advice in this study.

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