

Introduction

With the transition from film-based to digital image acquisition and reporting, there is a need to alter the environment of the reading room in the radiology department to optimise the performance of radiologists who are working in the room (Rostenberg 2009). Ideal environmental conditions for radiographic interpretation have been established for hard-copy films but they have not been determined for soft-copy images (Pollard et al. 2012). While there are many factors that contribute towards the work environment of the reading room, this paper will focus on ambient lighting and explore how we can measure its effect on detection performance.

Ambient lighting is one of the features that could affect the reading of images and is understood to be a highly essential aspect in terms of the detection performance and comfort of the radiologist (Pollard et al. 2009). Low ambient lighting is ideal for maintaining perceived image contrast as light can reflect off the surface of the display under high ambient lighting conditions and increase brightness on the screen in the dark portions of an image (Chawla & Samei 2007). However, the drawback to this is that radiologists may face eye fatigue which could eventually lead to a decline in performance (Chawla et al. 2007). This is due to the contraction and dilation of the pupils as the radiologist's focus of vision constantly changes between the high luminance screen (L_{adp}) and low luminance surroundings (L_{s}) (Figure 1).

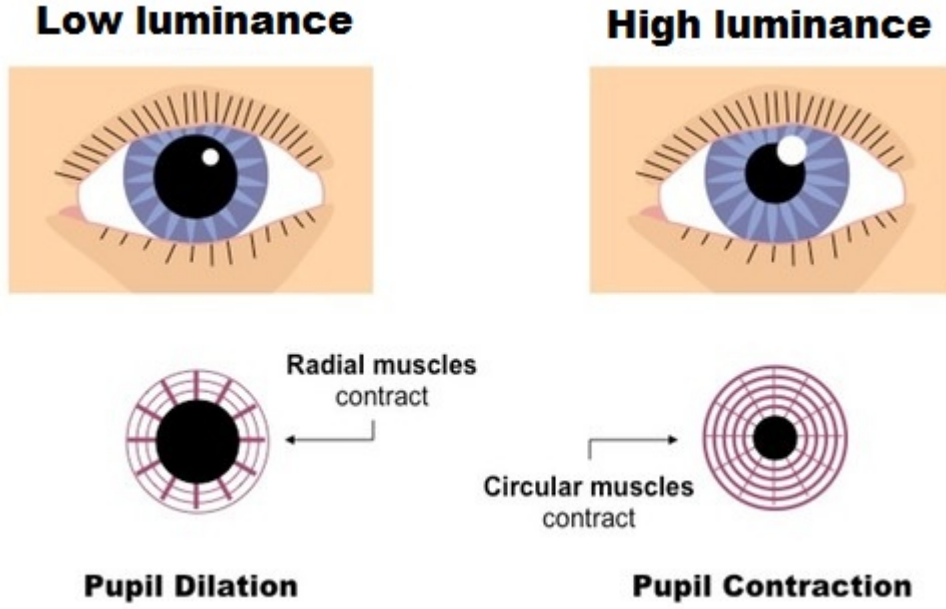


Figure 1. Under low luminance, more light enters the eye as the pupil dilates. Sympathetic nerve impulse is stimulated. There is relaxation of the circular muscles and contraction of the radial muscles. Under high luminance, there is contraction of the pupil and less light enters the eye. Parasympathetic nerve impulse is stimulated. There is contraction of the circular muscles and relaxation of the radial muscles (Friedman & Kaiser 2007).

The strain on the eyes may be reduced by minimising the difference between L_{adp} and L_s (Chawla et al. 2007) and this can be described in Equation 1 as follows (Pollard et al. 2008):

$$\min\{f\} = \min \left\{ \left| E \cdot R_s - \frac{40^2}{X_0^2} 10^{2.5 \tanh^{-1}[(5-d_{\text{adp}})/3]} \right| \right\} \quad (1)$$

where L_s is the product of the illuminance of the room, E , and diffuse reflection coefficient, R_s , of the surrounding objects; L_{adp} is represented by $x_0^2 = \pi D^2/4$ with D as the angular field

diameter to which the eye is adapted, which is around a value of 11° ; d_{adp} is the diameter of the pupil at L_{adp} . While d_{adp} can change depending on the nature of the work, it is assumed to be adapted to a rather constant diameter.

From Equation 1, we can see that to minimise the change in pupillary diameter and therefore eye strain, the adaptation luminance level of the visual system needs to be the same as the diffuse reflection luminance of surrounding objects. This would mean increasing the illumination of the room (Pollard et al. 2008). However, as mentioned earlier, there is a conflict of interest as high ambient lighting conditions can result in reduced image contrast. As such, we are interested to find out what the ideal ambient light level that would not compromise on a radiologist's performance but also be sufficiently comfortable to work in might be.

Measuring Detection Performance

There may be four possible scenarios after the radiologist has classified the radiographs as having positive or negative findings. These include:

True positive (TP): A radiograph with positive findings has been correctly classified as having positive findings.

True negative (TN): A radiograph with negative findings has been correctly classified as having negative findings.

False positive (FP): A radiograph with negative findings has been incorrectly classified as having positive findings.

False negative (FN): A radiograph with positive findings has been incorrectly classified as having negative findings.

These results may be expressed as a 2x2 contingency table as follows:

Table 1. 2x2 contingency table representing four possible scenarios.

	Actual findings		
Radiologist's classification	Positive	Negative	
Positive	TP	FP	Positive predictive value, $PPV = 100 \times TP/(TP+FP)$
Negative	FN	TN	Negative predictive value, $NPV = 100 \times TN/(TN+FN)$
	Sensitivity = $100 \times TP/(TP+FN)$	Specificity = $100 \times TN/(TN+FP)$	Accuracy = $100 \times (TP+TN)/(TP+FP+FN+TN)$

Sensitivity refers to how well a radiologist is able to correctly classify a radiograph as having positive findings (Parikh et al. 2008). Specificity refers to how well a radiologist is able to correctly classify a radiograph as having negative findings (Parikh et al. 2008). While these are able to evaluate how well the radiologist has performed under different ambient lighting, it does not take into account the diagnostic confidence level of the observer to differentiate the radiographs as having positive or negative findings (Beutel et al. 2000). If this confidence level differs, sensitivity and specificity will vary as well. Therefore, we cannot completely assess a radiologist's performance in classifying images as having positive or negative findings by simply using sensitivity and specificity as it does not describe the full range of the radiologist's detection performance (Park et al. 2004). Instead, there is a need to take into account the

tradeoffs between sensitivity and specificity and using a receiver operating characteristic (ROC) curve provides a graph of these tradeoffs (Beutel et al. 2000).

An ROC curve can be constructed by plotting sensitivity on the y-axis and false-positive rate (FPR) on the x-axis (Figure 1). FPR is also 1-specificity. The area under the ROC curve (AUC) describes how accurate radiologists are in their interpretation of radiographs under different ambient lighting conditions. A larger area represents higher accuracy (Fletcher & Fletcher 2013). Figure 2 shows examples of four different ROC curves.

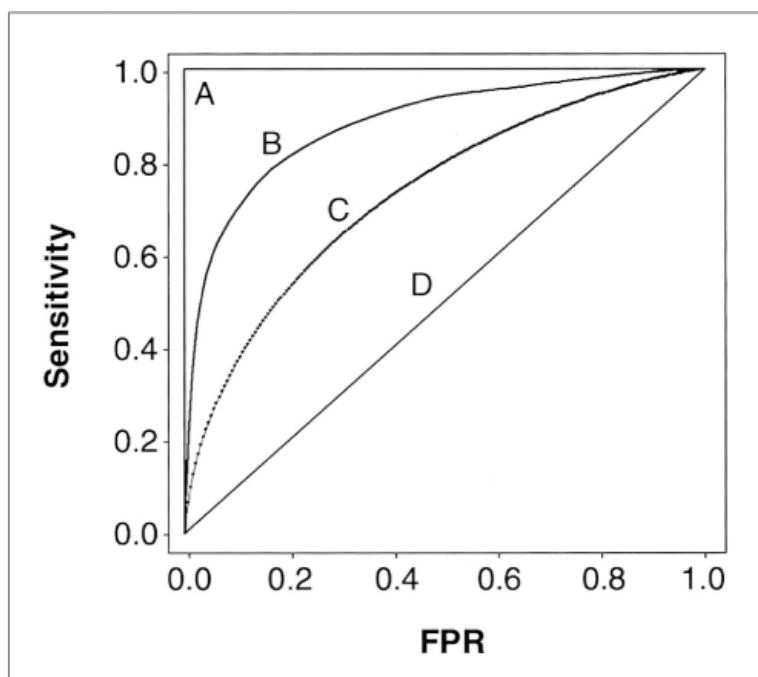


Figure 2. ROC curve A is a perfect test. It has an AUC of 1. ROC curve D is a chance diagonal and has an AUC of 0.5. Curve B has a higher AUC than curve C (Park et al. 2004).

From Figure 2, ROC curves of the radiologist's classification will usually lie between the two extremes of curves A and D and be represented by either B or C. The AUC should be greater

than 0.5 as it is less dependent on chance and shows that the observer is able to differentiate between radiographs with positive or negative findings (Park et al. 2004).

Equal AUC values show that the overall detection performance of the radiologists was the same but it does not necessitate that they had the same ROC curves. Figure 3 shows two ROC curves, A and B, which have the same AUC but we can see that they are of different shapes. In this case, curve A suggests that the radiologist performs better in the low FPR range with lower sensitivity whereas curve B suggests the the radiologist performs better in the high FPR range with higher sensitivity.

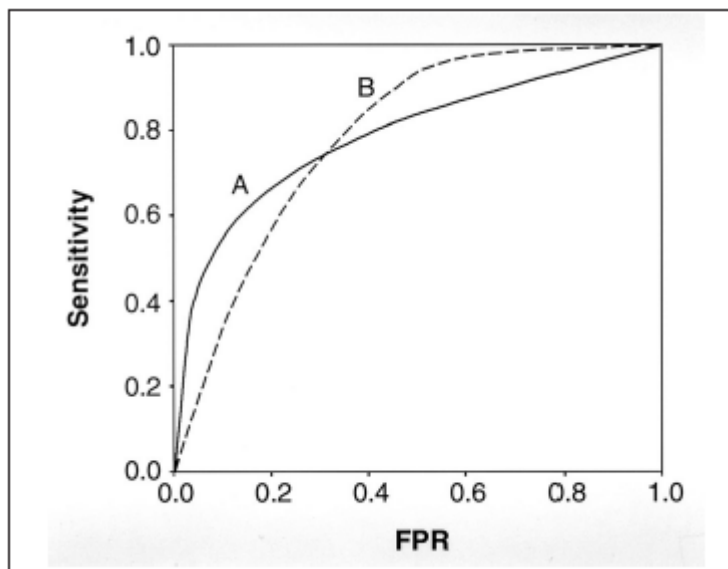


Figure 3. ROC curves A and B have the same AUC but have different shapes (Park et al. 2004).

Futher Discussion

Studies conducted on the effect of ambient lighting on radiologist detection performance suggest various values of ambient lighting for the reading room depending on the region on interest. For instance, Brennan et al. (2007) suggested that the optimum ambient light conditions for reporting of wrist radiographs to be 25-40 lux while Pollard et al. (2012) suggested that 50 lux would be ideal for chest radiology reading rooms. The general consensus is that levels at 40-50 lux are optimal (Brennan et al. 2007; Pollard et al. 2009; Pollard et al. 2012). At 50 lux, radiologists could comfortably perform other tasks that might be required of them but it was low enough such that the detrimental effects on image contrast due to specular reflection were insignificant (Samei et al. 2005). Calibrating the liquid crystal displays (LCDs) used to view the images will also help to make up for a small increase in lighting without compromising on image contrast (Samei et al. 2005). LCDs should be calibrated in compliance with the American Association of Physicists in Medicine Task Group 18 (AAPM TG18). Under these guidelines, an ambient lighting level as high as 150 lux may be even be used (Pollard et al. 2008).

However, even though most clinical places are advancing towards using LCD monitors, the studies performed to determine optimal ambient lighting in reading rooms that utilise them are few. Furthermore, there are only four radiologists included in the studies by Pollard et al. (2009) and Pollard et al. (2012), putting a limit on the conclusions. Also, the studies tend to focus on a particular region but in reality, radiologists will read images of different regions over the course of a day.

It must be noted that the duration that radiologists spent inside the reading room for studies on the effects of ambient lighting on detection performance of radiologists was short and the results may differ for an extended period of time. While an increased ambient light level may potentially reduce eye fatigue, it does not eliminate it completely and detection performance could decrease after a few hours. However, based on the findings that increased ambient lighting generally leads to better performance on the radiologist's part, it could be worth investigating if increasing the ambient lighting again after a few hours of being in the reading room would maintain or even improve detection performance. Research could also be conducted to determine if there are any changes to the average selection time.

While ambient lighting plays an important role in detection performance, there are other factors to consider as well. These could include the experience of the radiologist, type of monitor used and even the radiologist's eyesight. A combination of various aspects contribute to the overall performance of the radiologist. However, the significance of ambient lighting in the work environment should not be underestimated and more studies should be carried out to gain a better understanding on its effects on detection performance.

References

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