The effect of viewing conditions on reader performance in radiographic images

Maryam Mojiri * [1], Karim Ghazi Khanloo Sani [2] , Abbas Moghimbeigi [3]

[1]Radiology Department, Paramedical School, Hamadan university of medical science, Hamadan , Iran.
[2]Radiology Department, Paramedical School, Hamadan university of medical science, Hamadan , Iran .
[3]Department of Biostatistics and Epidemiology, Research Center for Health Sciences, Hamadan University of Medical Science, Hamadan, Iran

*Corresponding Author: email address: mojiri@umsha.ac.ir (M. Mojiri)

ABSTRACT:

Accurate interpretation of radiographic images is dependent on viewing conditions. Recently the number of radiology departments has been increased so it needs to use a workstation for reporting. The aim of this study was assess monitor performance and the effect of viewing conditions on object detection. This investigation aimed to quantify the effects of changes in box brightness and ambient light level on reader performance. Radiographs of the contrast-details phantom were taken in multiple exposures and were viewed by six observers. The viewing test was performed in 50,100 and 150 lux of ambient light in compound with 1000,1500 and 2000 cd m^{-2} box brightness. The percentage of uniformity was also 85. The results were analyzed by SPSS software. Low contrast visibility generally increased when the ambient light was 100 lux. The greatest performance was obtained in 2000 cd m^{-2} brightness and 15% non uniformity in mentioned ambient lighting. Reader performance not affected by ambient light and view box luminance although it seems those factors influenced on detection of low-contrast features in some studies.

Keywords: Radiography; Image; Observer performance; Detectability

INTRODUCTION

The most effective way to reduce patients' absorbed dose is to use quality assurance technique while radiograph quality not decreased [1].The international commission on Radiological protection (ICRP) recommends that the individual absorbed doses should be kept as low as reasonably achievable (the "ALARA" principle) by optimization of protection, exposure factors and other effective objectives [1]. The accuracy of diagnosis and the effectiveness of a radiology service are influenced by the conditions under which radiographic image are viewed [2]. This means viewing conditions are an important variable when the diagnostic images are interpreted [3]. Optimization of viewing condition, facilitate the detection of low contrast in small dimension. To maximize visual acuity, it is important to achieve suitable luminance. In diagnostic radiology, viewing boxes named Negatoscope, has an important role on detection accuracy besides the ambient light. When light intensity is lower than needed, the eye loses power to detect small objectives [4].Viewing boxes with low brightness will limit visual acuity, the light reaching the observers' eye and will reduce the ability to perform adequate assessment of radiographs' details[5]. Some studies have reported that different environment have effects on the amount of diagnostic information. Several investigations concerning the effect of viewing conditions have shown that view box luminance affects reader performance under different conditions. For example, view box luminance enhance the reader's ability to detect low-contrast objects, while high luminance improved[6]. They showed view box luminance and ambient lighting significantly affected the detection of calcification, particularly at the highest film densities. On the other hands other studies have reported that negatoscopes' illumination do not affect reader performance. They investigated the visibility of low-contrast and fine details as a function of view box and they found that view box luminance had no significant effect on reader performance for the investigated range of film densities [6]. Many researchers in diagnostic radiology have only concentrated on absorbed dose and image quality optimization. They ignore the viewing conditions while view boxes are vital aspects of the image viewing process. Although it involved the low cost, institutions often spend the huge amount of money on acquiring new imaging devices instead of investigation and change the viewing condition. According the texts there is no internationally agreed viewing standards. Different guidelines published by USA and Commission of the European communities (CEC) and NORDIC (Denmark, Finland, Iceland, Norway and Sweden). While conventional radiography is interpreted, the American College of Radiology (ACR) was indicated the amount of 1500 cd m^{-2} or nit for view box illumination. In the same condition, 2000-4000 and 1500-3000 cd m^{-2} was defined by European Commission and British institute of Radiology respectively. These guidelines for the parameters viewing box luminance, uniformity of viewing box and ambient light are summarized in table 1 [7, 8, 9, 10, 4, 5].

Table1. Existing guidelines for view box Illumination and ambient light

Organization	Illumination (cd m-2)	Ambient Light (Lux)
WHO (1992)	1500-3000	≤ 100
American college of Radiology	1500	----
CEC (1996)	2000-4000	Low level
CEC (1997)	≥ 1700	≤ 50
British institute of Radiology	1500-3000	50-100
NORDIC	1500-3000	≤ 100

The objective of this study was to evaluate the importance of view box luminance and also ambient light on reader performance and how they affect on detection of low-contrast details.

MATERIAL AND METHODS

According to the references we examined three view boxes luminance as 1000, 1500 and 2000 cd m^{-2}. The investigated ambient lights were 50, 100 and 150 lux. In order to obtain these conditions, luminance measurements were made on total view box panels located in throughout Hamedan teaching hospitals. The measured view box panels were made by different manufacturers. A calibrated photometer model Hagner Universal S2 was used to measure the luminance in lux and the cd m^{-2} in this study. The measurements were carried out at approximately 1cm from the surface of the panels. We tried to measured luminance as possible as all locations in the surface of view boxes (more than 100 locations per each view box) and the average luminance was calculated for each one. Among obtained data three view box with above mentioned luminance were chose.Then different three ambient lights (50,100 and 150 lux) were prepared as a needed condition. This is conducted after determination of ambient light in three locations where the selected view boxes use by making some changes in rooms light. To take radiographs we used a low-contrast phantom constructed of acrylic. Ten rows and columns considered and they included 100 holes (disks) in total. For each row, disk thickness is varied from 0.3 to 7.95 mm from left to right which makes different contrast. Also the diameters of the disks change in a mentioned range from top to bottom, thus in each row, the holes have a single diameter but different depths and the disks in each column had a single depth and different diameter [6].

To prepare similar condition for taking radiographs we used one X-ray machine, medical model, one radiology cassette in size 18x24 cm, Fuji film and all exposed films processed just by a processor, hope model in 28^{o} c. we used six kVp and six mAs to make different range of optical densities (0.5, 1 , 1.5 and 2). All radiographs of the phantom were taken under following conditions: total filtration 2.8 mm Al and focus-film distance 100 cm and no distance between phantom and cassette. Then the film densities were measured by a densitometer. The designed form was used to indicate what holes are visible in each row and column. It was exactly same to the phantom design. Six radiology technicians with average age 30 years participated in this study as readers. Then each reader (technician) determined the number of disks visible and indicated the exact location of the disks on row and column.

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Then each reader (technician) determined the number of disks visible and indicated the exact location of the disks on row and column. The first experiment investigated the effect of room luminance on reader performance. It was done by changing the condition regarding the ambient light. All the observers read total of radiographs in three ambient luminance (50, 100 and 150 lux) while the view box luminance and non uniformity was 1000 cd m^{-2} and 15% respectively.This process was reduplicated in 1500 and 2000 cd m^{-2} of view box brightness while the uniformity was firm. All of the phantom images were positioned in the center of the view box for evaluation. The obtained data was analyzed and the best ambient light among surveyed conditions is 100 lux and it was used for following our investigation.

The second examination evaluated the effect of view box luminance on reader performance by considering the three conditions (1000, 1500 and 2000 cd m^{-2}) while the ambient light was 100 lux and non uniformity not changed (15%).

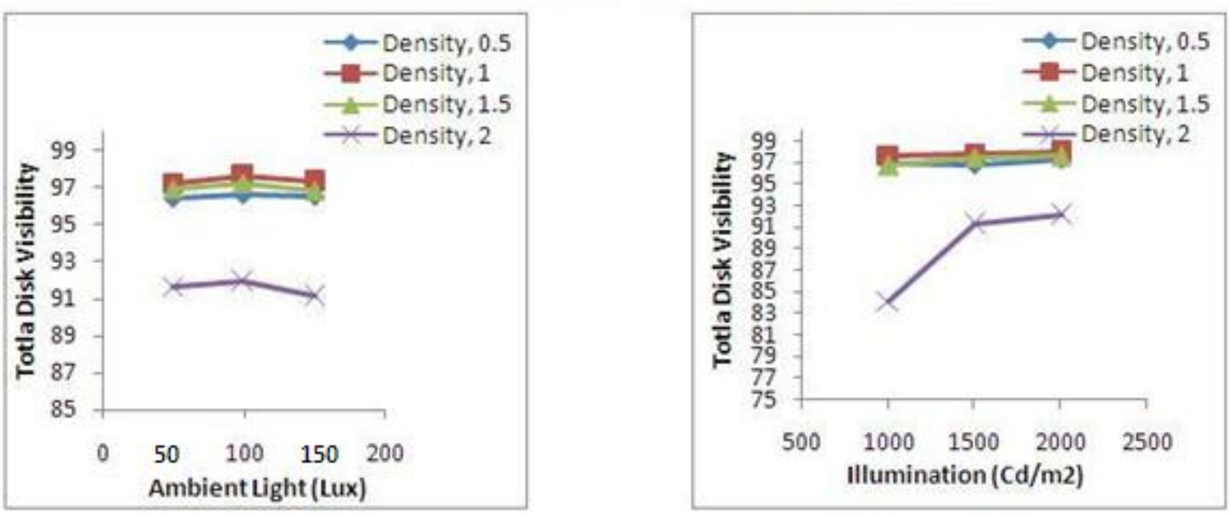
The distance between the view box and observer's eyes averaged 30cm for both parts of our study.

The obtained data was statistical analyzed by SPSS software No.13. Repeated measure analysis was used for all visible disks by using the results after each stage and compared it with the others. For instance in the first examination, the results of three conditions regarding ambient light compared to each other. To assess detectablity, C-D diagrams were made from the average value recorded by each observer per each viewing condition. The curves express the discrimination areas which are above each curve and indicates detectability. The tables and diagrams created to support our taken information from the current study.

RESULTS

Figure1 displayed the average number of disks reported by six participated readers in four categories phantom image as a function of ambient light room and illumination.

Figure1. Disk visibility as a function of ambient light room and Illumination



As it delivered from data which has been displayed in figure1, the maximum visible disks obtained in 100 lux of ambient light and 2000 cd m^{-2} of view box brightness.

In all densities, the mentioned amounts of ambient light and brightness prepare best condition to read phantom images. Repeated-measures analysis of variance (ANOVAs) was performed to investigate the effect of character ambient light on reader performance.

It was also used for determination of the best view box luminance and its' effect on total disk visible as a reader performance.

There are a significant different on reader performance for two groups of densities regarding the ambient light room, density 1 (*p value*= 0.05) and density 1.5 (*p value*= 0.007).

To evaluate the effect of view box brightness on reader performance, the above mentioned analysis was used and the results showed no significant different on visibility disks as a reader performance for two groups of density 0.5 and 1 while the other two groups displayed statistical significant different, density 1.5 (*p value*= 0.02) and density 2 (*p value*= 0.00). Figure2 has supported the above mentioned findings.

Figure2. Significant difference for density groups in three conditions of ambient light and illumination

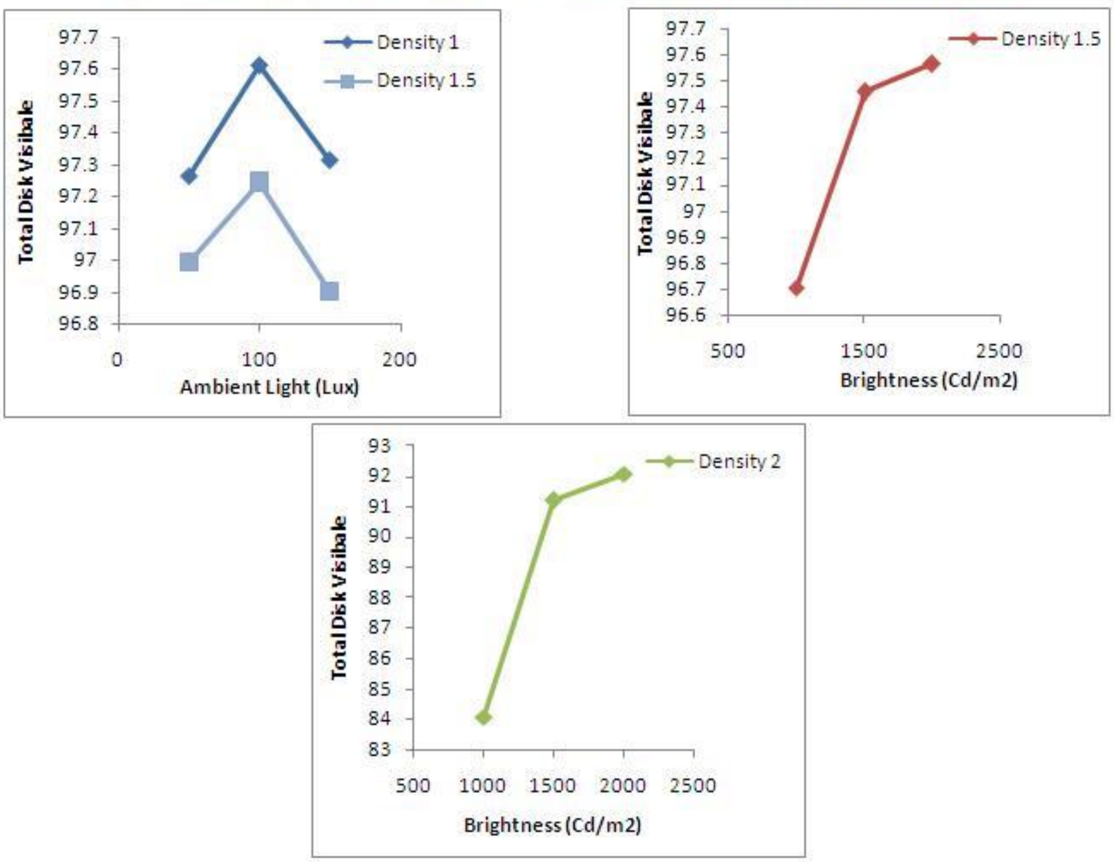


Figure3 shows the C-D diagrams at four optical densities group under the three viewing conditions regarding ambient light and also illumination of view box. The values are the averages of the six observers. If all 100 holes were discriminated, the detectability would be maximal at 7.95.

The Contrast-Details diagrams are according the diameter on horizontal axis to indicate details, while the vertical axis is the depth, indicating contrast. In four categories density, the detectability was highest in 100 Lux ambient light and 2000 cd/m^2 as illumination of view box.

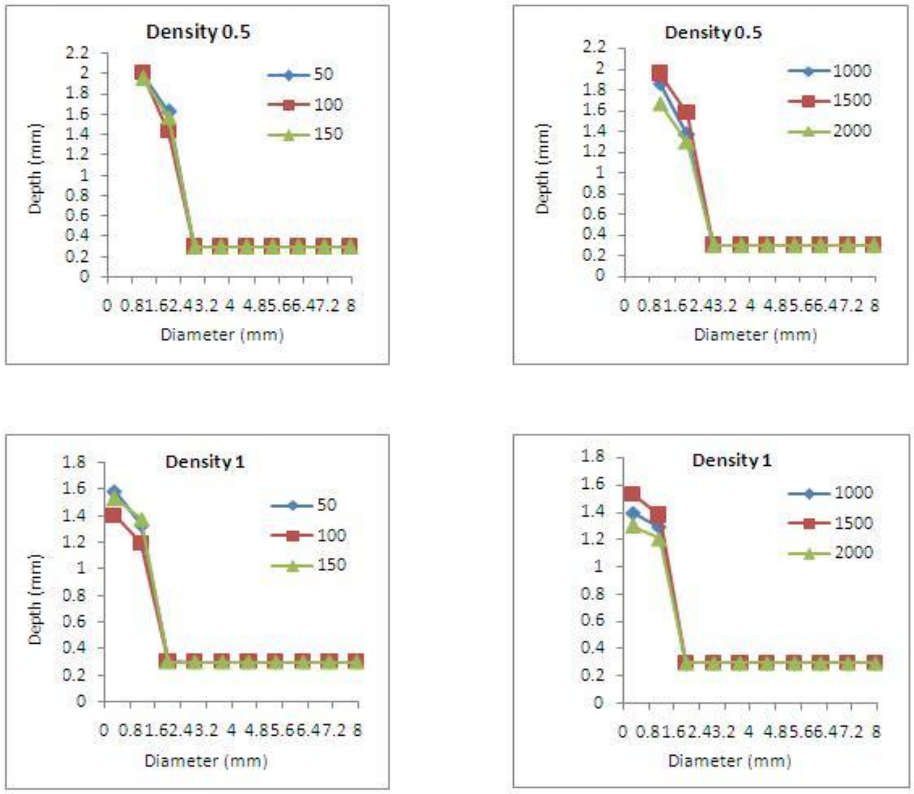
Table2 summarizes results of the statistical analysis at each of four densities studied.

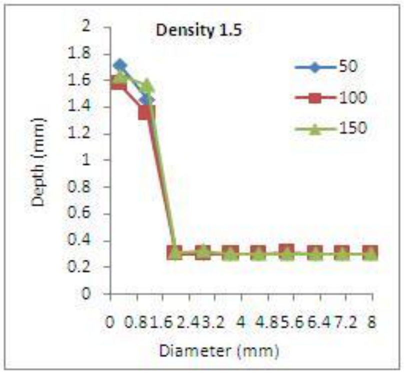
There is one exception for ambient light in density groups 1.5 and two exceptions for illumination in density groups 1.5 and 2.

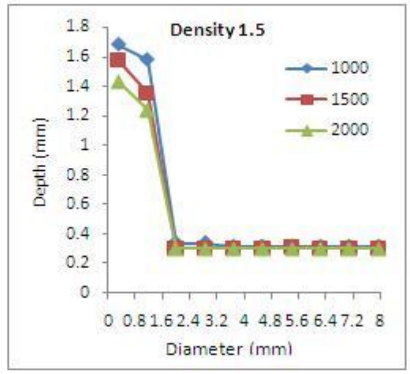
Table2. Effect of Ambient light and Illumination on Reader performance in four density groups

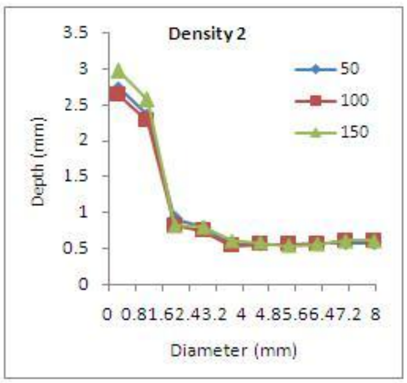
P value from Repeated measure test		
Film Density	Ambient Light	Brightness
0.5	0.896	0.331
1	0.058	0.123
1.5	0.007*	0.026*
2	0.313	0.000*

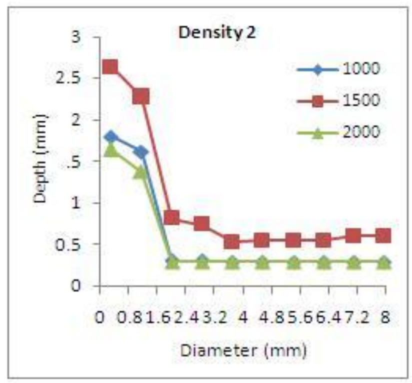
Figure3. Contrast-Details diagrams for four densities groups in different conditions of Ambient light and Illumination











DISCUSSION

One of the main aspects of radiography process is to acquire as much information as possible from radiographs in order to reduce costs and advance the social interests of patients who undergo X-ray examination. To this end, it is important to suit the best condition regarding both viewer and environment. However, the viewing situation is not considered in many clinics.

Our measurements included 36 phantom images in four densities delivered from six kVp in combination with six different mAs. The total number of visible disks in different radiology images used to draw diagrams to evaluate the effect of ambient light room. We suggest the ambient lighting of 100 lux to read the images among three investigated lighting. It could be compared to amount of ambient light room which has been recommended by WHO, British institute of Radiology and also NORDIC. Besides that in this study the best luminance of view box, obtained 2000 cd m^{-2}. It is higher than the suggestion of American College of Radiology (ACR) but this finding is in good agreement with published recommendation of WHO, CEC, British institute of Radiology and NORDIC. The results of this study displayed that ambient lighting room as a considered parameter in reading room, had a negligible effect on reader performance and our findings are not in agreement with those which presented by Hill et al [11]. They evaluated the effect of view box luminance on low-contrast visibility and found that mentioned luminance had no significantly effect on reader performance. They explained a bright of view box does not improve the overall signal-to-noise ratio, so reader performance does not affect by it. This study demonstrated that viewing condition such as ambient lighting room can affect on reader performance. They showed that low ambient light and restricted lighting from surrounding view boxes significantly improved low-contrast detection performance on films with a density of approximately 2.00. Clearly using low ambient lighting is required to detect low-contrast details.

Past surveys explained that by lowering the illumination in the environment, the detectability would be improved further [12, 13].

Welander et al [14] examined the effect of the viewing environment on detectability using different exposures. The intensities of the light from the view box and in room were not mentioned, however when the light from the view box and room lights was not blocked by special device, they reported that the detectability fell. In this study they found that low-density radiographs are hardly affected by the viewing environment and that high-density radiographs are capable of providing high detectability when observed. These findings are conflict with those we obtained in present study. Other investigations by researchers such as Kanamori [12] determined that the optimum density ranges which the observers can identify were 0.2-1.6 in 2000 lux brightness of view box.

Moreover there are many researches around detectability of some abnormalities in radiographic images from patients. For instance Gin Mo Goo [15] explained that the level of digital monitor luminance had no significantly effect on detection of any of the three abnormalities. Herron et al [16] reported that the detection of some diseases such as pneumothorax and rib fracture showed statistically significant differences due to the luminance. Ikeda et al [17] showed that lower view box luminance resulted less detection of nodules on chest radiographs while the ambient light was high (200 lux).

It should be noticed that performance factors for reading the radiographs on view boxes are not yet completely understood. The level of luminance has an important role in detecting structures with low contrast, particularly those in regions of high absorption. The responsible factor is may be adaptation to the dark. It seems when the viewers began observation 2 to 3 min in a darkened room they adapted and higher detectability might be expected. But it is unrealistic and impractical to wait for darkness adaptation.

The monitor luminance and ambient light conditions, which impose stricter lighting requirement in the reading room, may result in observers' inability to engage in long reading sessions because of inability to concentrate. On the other hands, the results of the fatigue scoring showed that the viewers felt more fatigue with a high level of ambient light and monitor luminance than with other conditions. So there are however, some aspects of view box luminance that this study did not address. For example the age of the reader may be a factor that could also affect performance. In this study the average age of reader was 30 and different results could be possible with younger or older groups of readers. Additional factors that may be relevant include reader fatigue, the time required to read images [6].

Moreover it is relevant to consider our results for any quality control procedure involving view boxes. For instance, illumination of view boxes is reported to have typical life expectancies of approximately 20,000 hours and a light output that decreases by 20% after 18,000 hours.

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