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A method to determine the impact of reduced visual function on nodule detection performance

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ABSTRACT

Purpose: In this study we aim to validate a method to assess the impact of reduced visual function and observer performance concurrently with a nodule detection task.
Materials and methods: Three consultant radiologists completed a nodule detection task under three conditions: without visual defocus (0.00 Dioptres; D), and with two different magnitudes of visual defocus (−1.00 D and −2.00 D). Defocus was applied with lenses and visual function was assessed prior to each image evaluation. Observers evaluated the same cases on each occasion; this comprised of 50 abnormal cases containing 1–4 simulated nodules (5, 8, 10 and 12 mm spherical diameter, 100 HU) placed within a phantom, and 25 normal cases (images containing no nodules). Data was collected under the free-response paradigm and analysed using Rjafroc. A difference in nodule detection performance would be considered significant at $p < 0.05$.
Results: All observers had acceptable visual function prior to beginning the nodule detection task. Visual acuity was reduced to an unacceptable level for two observers when defocussed to −1.00 D and for one observer when defocussed to −2.00 D. Stereoacuity was unacceptable for one observer when defocussed to −2.00 D. Despite unsatisfactory visual function in the presence of defocus we were unable to find a statistically significant difference in nodule detection performance ($F(2,4) = 3.55$, $p = 0.130$).
Conclusion: A method to assess visual function and observer performance is proposed. In this pilot evaluation we were unable to detect any difference in nodule detection performance when using lenses to reduce visual function.

Introduction

It is recognised that interpretation errors occur in radiology and while it is more difficult to assign a definitive cause for them, they are typically split into three different classes: search, recognition, and decision.[1] There has been a heavy focus on error in medical imaging research, in an attempt to both understand and reduce the cause. A broad investigation of error requires consideration of confounding factors, such as education and training, expertise, visual perception and search.[2–10]

Fatigue is known to have an impact on error rates, where there is a reduction in optimal cognitive performance. It has also been found to have a negative influence on observer performance[11,12] and some work has been devoted to methods that can help combat the effects of fatigue.[13,14] Ikushima et al.[13] have assessed the relationship between fatigue and visual acuity, finding visual acuity to be better when there is less fatigue. However, very little work has investigated the impact of sub-optimal visual acuity on observer performance.[15]

This may present a problem in radiology. Visual acuity is known to decrease with age and currently there is no legal requirement for radiologists or reporting radiographers to undergo a vision test on a regular basis. Safdar et al.[16] allude to this where they point out that while a great deal of attention has been paid to the quality control of digital displays, the same cannot be said for those who examine images. They continue to explain that not every radiologist in their study of visual acuity had 20/20 vision. Two key points were made: (i) some of the radiologists required visual correction and, (ii) some

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had gone without a vision test for 15 years. Without a regular vision test it can be difficult for an individual to recognize that their quality of vision has reduced. The symptoms of decreased visual function may be gradual and may not be perceived by the individual to be related to vision and they may complain of other secondary symptoms like headaches or red, sore, watery eyes. We hypothesize that a reduction in visual acuity, consistent with age, may have a negative impact on observer performance (i.e. a reporting task). We believe that there cannot be many other professional roles that have the potential to be so dependent on visual acuity, and also have the chance to be so heavily influenced by a reduction in acuity.

Several measurements of visual function have been proposed to help determine the impact of deteriorated vision in medical imaging.[17] In this study we aim to validate a method to artificially induce a reduction in visual function and assess observer performance concurrently with a nodule detection task.

Method

We assess nodule detection performance and visual function under normal conditions (no reduction in visual acuity) and with two-levels of optically induced eye defocus. Observer responses were collected under the free-response receiver operating characteristic (FROC) paradigm. Ethical approval was granted by the Lisbon School of Health Technology.

Visual function assessment and visual defocus

Optically induced defocus was applied with lenses in order to reduce retinal image contrast and alter the spatial frequency,[18] thus causing a blurring effect for near vision. The refractive power (dioptres; D) of an optical system is the reciprocal of the focal length of a lens.[19] Defocus using lenses in the magnitude of −1.00 D, −2.00 D and 0.00 D were applied to the observers in a random order.

Prior to each image evaluation, each observer's visual function was assessed to ensure it was within normal limits. Visual function was not expected to be within normal limits when the lenses were applied to induce defocus, as the purpose of the work was to assess observer performance with reduced visual acuity. The acceptable limits of the visual function tests used are described in Table 1. The tests for visual function assessment in medical imaging research are described in more detail in a previous paper.[17] Contrast sensitivity was measured only prior to defocussing vision; this was to ensure that the contrast sensitivity of the observers was within normal limits for performing visual tasks prior to beginning the observer study.

Table 1
A summary of acceptable visual function for the tests used to evaluate visual function prior to the image evaluations. With a visual acuity of 20/50 for near vision the observer can read a column of newsprint with an 8-point font size. Contrast sensitivity values are for mesopic conditions (low light level). The instrument automatically controls the test lighting to a level of 85 cd/m^2. Stereoacuity is better when the angle is smaller.

Visual function test	Summary of observer requirements
Visual Acuity	Near visual acuity should be better than[20]: • 20/50
Contrast Sensitivity	Considered normal when[21]: • ≥1.61 for gratings of 3 cycles per degree • ≥1.66 for gratings of 6 cycles per degree • ≥1.08 for gratings of 12 cycles per degree • ≥0.56 for gratings of 18 cycles per degree
Stereoacuity	Normal values should be equal or smaller than:[22] • 50 s of arc

Prior to completing an image evaluation with lenses (i.e. at −1.00 D and −2.00 D) an adaptation period of 10 min was enforced. There is no current standard for this, as it is not typical to make the vision of an observer worse before they begin an observer performance study. However, we felt that an adjustment period was appropriate, but that should remain short since previous work has identified blur adaptation to lenses in the magnitude of 2.00 D, with improved visual performance after wearing lenses for 60 min.[23] Each image evaluation lasted approximately 40 min. Rest periods were permitted, but no observer required a break mid-evaluation.

Image display

Postero-anterior radiographic images of an anthropomorphic chest phantom were used for the observer study. Images of the phantom without simulated nodules were considered 'normal'. Images of the phantom containing different configurations of simulated nodules of 5, 8, 10 and/or 12 mm spherical diameter were considered abnormal. All nodules were placed within the phantom and we did not use any digitally superimposed nodules in this study. For the observer study there were 50 different configurations of nodule position, with 1–4 nodules present in each abnormal image. A nodule of each size could only appear once in each abnormal image but there was freedom to place the nodules in any position within the simulated lungs of the phantom. Twenty-five normal cases were also used. The mean signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) of the nodules was 1.08 ± 0.05 and 0.60 ± 0.33 respectively. Nodule measurements were achieved with a circular region of interest (ROI) fitted to the size of the nodule; background measurements were achieved using a circular ROI that included the nodule and the immediate surrounding structures. The background ROI was approximately double the area of the nodule ROI. C Images were displayed on a 2.3-megapixel monitor (*Barco MFCD 1219, Barco, Belgium*) calibrated to the DICOM greyscale display function standard. Ambient luminance in the test room was measured to be 225 lux at the height of the eyes.

Observer performance study

Three consultant radiologists (age range 31–50, and 5–18 years reporting experience) completed the observer study. All observers received training directed towards viewing normal images and a sample of images containing simulated nodules that were not used in the main study. All observers were shown how to use ROCView[24] for the collection of free-response data. Each observer was required to complete three image evaluations (0.00 D, −1.00 D & −2.00 D). Images were displayed in a different randomised order for all image evaluations. An image evaluation schedule is presented in Table 2.

Image display and the storing of free-response data were managed by ROCView.[24] Observers were instructed to localise all simulated nodules. This was done using a mouse click. Each localisation would prompt a slider-bar confidence scale (1–10) to appear. The scale worked from left (1; low confidence) to right (10; high confidence). All localisations were classified as either lesion localisation (LL) or non-lesion localisation (NL) using an acceptance

Table 2
Each observer completed the observer study in a different order to reduce the dependence of evaluation order on the overall result.

Observer (age)	Evaluation 1	Evaluation 2	Evaluation 3
1 (50)	−1.00 D	0.00 D	−2.00 D
2 (35)	−2.00 D	−1.00 D	0.00 D
3 (31)	0.00 D	−2.00 D	−1.00 D

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