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

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Aims and objectives

There are few professions in which visual acuity is as important as it is to radiologists [1]. The diagnostic decision making process is composed of a number of events (detection or observation, interpretation and reporting), where the detection phase is subject to a number of physical and psychological phenomena that are critical to the process [2]. Visual acuity is one phenomenon that has often been overlooked, and there is very little research assessing the impact of reduced visual acuity on diagnostic performance [3]. The aim of this study was to investigate the impact of reduced visual acuity on an observer's ability to detect simulated nodules in an anthropomorphic chest phantom.

Methods and materials

Summary

An anthropomorphic chest phantom containing simulated nodules was used for the detection task. The observers completed the task under three conditions: (i) normal visual acuity, (ii) reduced visual acuity (level 1), (iii) and reduced visual acuity (level 2). Observer data was collected under the free-response receiver operating characteristic (FROC) paradigm. Local ethical approval was gained prior to the commencement of this study.

Vision Testing and Reduction of Visual Acuity

The normal visual function of the observers was ensured using the tests described in a previous paper [4]. Lenses used in a traditional vision test were used to reduce the visual acuity of the observers. The lenses were used to reduce retinal image contrast and alter spatial frequency [5]. We will refer to this 'optically induced defocus'. Defocus was applied at two different levels. We based this on the dioptre (D) scale, which is a unit measurement of the optical power of a lens, equal to the reciprocal of the focal length of the lens [6]. This is reflective of a typical prescription lens. We applied defocus at -1.00 D and -2.00 D, and also at 0.00 D - this would be a refractive correction for some observers. Trial lenses were applied in a different random order for the five observers.

Anthropomorphic Chest Phantom

The anthropomorphic chest phantom (Lungman N1 multipurpose chest phantom, Kyoto Kagaku Company Ltd, Japan) was loaded with fifty different configurations of the following simulated nodules: 5, 8, 10 and 12mm spherical diameter, all measuring approximately 100 Hounsfield Units density. These would be used as 'abnormal' cases

in the observer study. Images were also acquired with no nodules present to provide 'normal' cases.

Observer Performance Study

Three radiologists (aged 31, 35 & 50) and two radiographers (aged 32 and 47) completed the observer study. Each observer completed the study in a different order. The observers were trained to understand the appearance of the phantom without nodules and were also introduced to sample images containing nodules that were not used in the observer study. Training requirements are minimal for phantom studies since there is no case variation.

All image evaluations were completed on the same specification of monitor (Eizo RadiForce GS521 10-Bit digital imaging and communications in medicine (DICOM) compliant monitor, 2048x2560, 5 megapixel resolution, Eizo Corporation, Japan) using ROCView [7] to complete the image evaluations. Ambient lighting was consistent at 225 lux.

The nodule detection task was completed under the FROC paradigm; observers were instructed to mark the centre of each nodule using a mouse click. This would prompt a 10-point rating scale to appear. Localisations were classified as lesion localisation (LL) or non-lesion localisation (NL) by an acceptance radius. The acceptance radius was set at 25, 50 and 100 pixels for this task. The average size of the largest nodule was 100 pixels diameter.

Statistical Analysis

Observer data were analysed using an R implementation of jackknife alternative FROC (JAFROC) analysis, Rjafroc, available at https://cran.r-project.org/web/packages/RJafroc/index.html. The weighted JAFROC figure of merit (FOM) defines the probability that a lesion localisation is rated higher than a non-lesion localisation on a normal case [8]. A difference in nodule detection performance was declared significant if the p-value of the overall F-test was less than 0.05 and the 95% confidence interval of the treatment difference did not include zero.

Results

Observer Performance Study

No statistical difference in nodule detection was found for the three treatments (conditions) using random reader fixed case analysis. The choice of acceptance radius had no impact on statistical significance ($F(2,8) = 1.41$, $p = 0.299$). The observer averaged FOM and 95% confidence intervals for all three treatments are displayed in Table 1 and Fig. 1 on page 4 for the strict acceptance radius (AR-25). The observer averaged AFROC curves for all three treatments are displayed in Fig. 2 on page 5. The treatment differences are display in Fig. 3 on page 6.

Table 1: Observer Averaged JAFROC FOMs (all treatments, AR-25)

Treatment	*JAFROC FOM (95% CI)*
0.00 D	0.606 (0.513,0.700)
-1.00 D	0.571 (0.487,0.656)
-2.00 D	0.596 (0.482,0.710)

Vision Testing

For near vision, visual acuity should be equal to or better than 20/50. Stereoacuity is measured in seconds of arc, and should be equal or less than 50. Contrast sensitivity was assessed with gratings of 18 cycles per degree, to assess vision at high spatial frequency; it should be equal to or better than 0.56.

For all observers, visual acuity and contrast sensitivity was acceptable at 0.00 D. For observer 3 (radiologist aged 50), visual acuity was not acceptable when lenses simulating -2.00 D were applied. However, this change in acuity was not influential on the nodule detection task. Stereoacuity was normal for all except observer 3.

Images for this section:

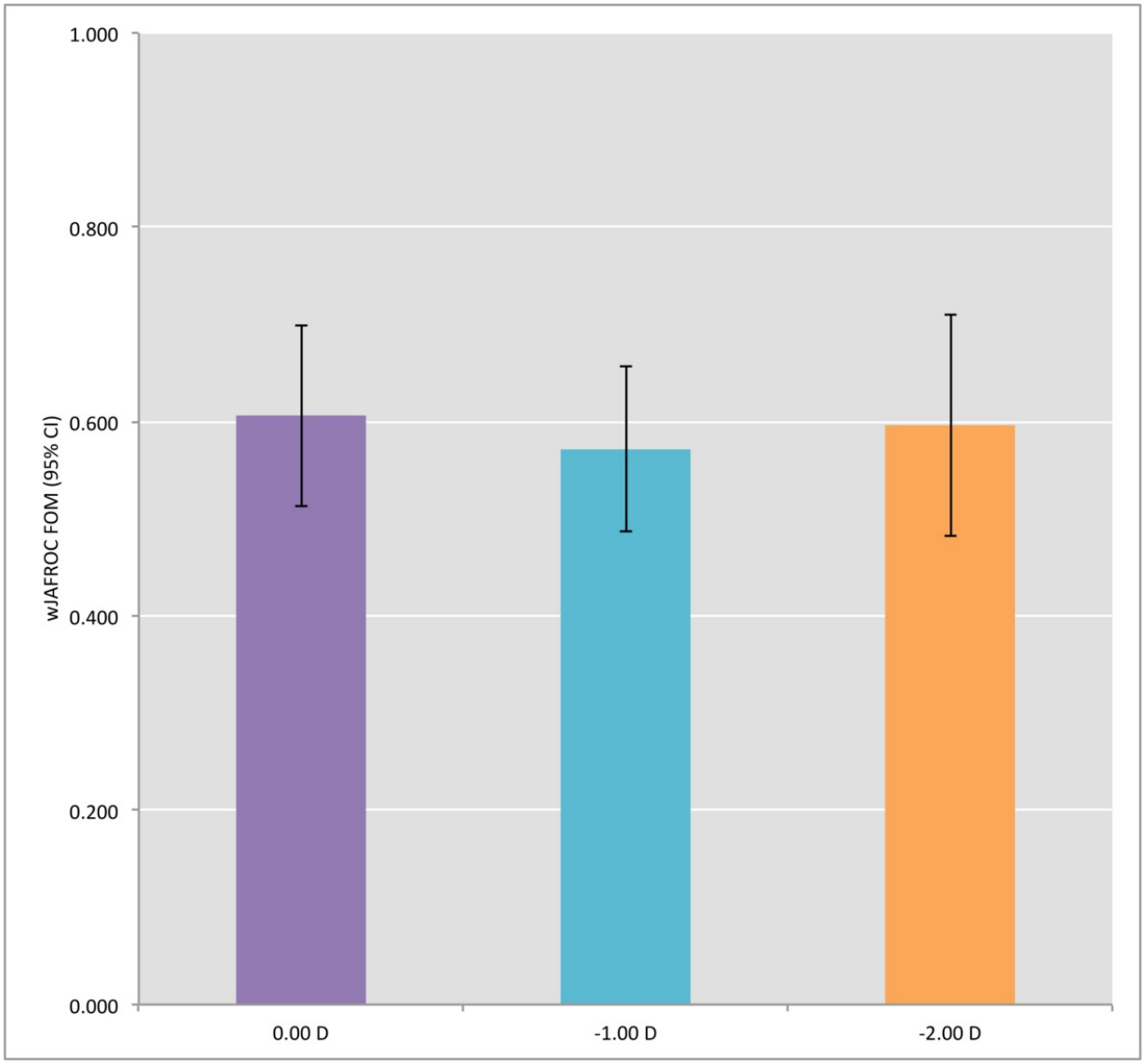

Fig. 1: The observer averaged wJAFROC figure of merit and 95% confidence intervals for all treatments.

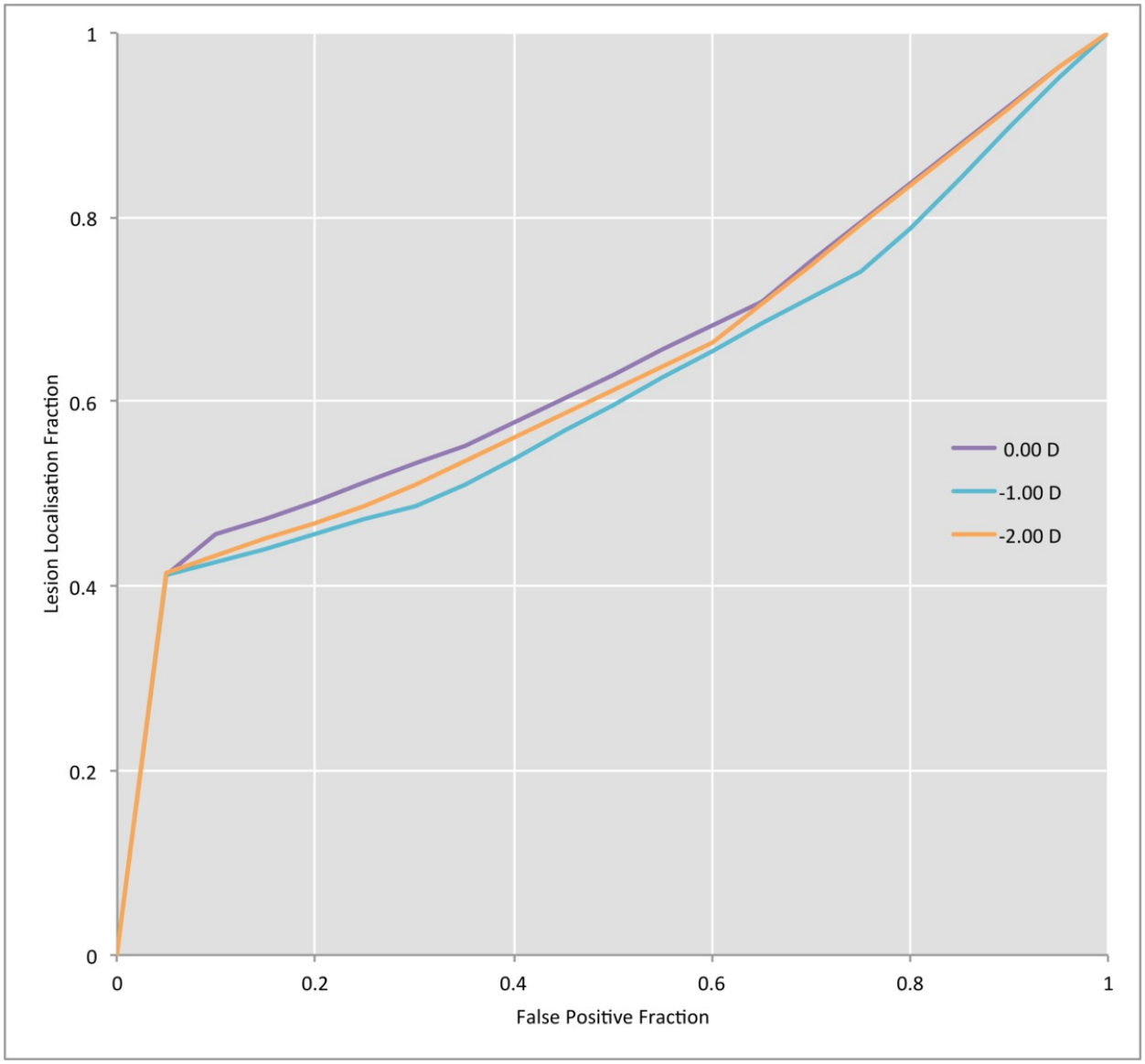

Fig. 2: The observer averaged AFROC curves for all treatments.

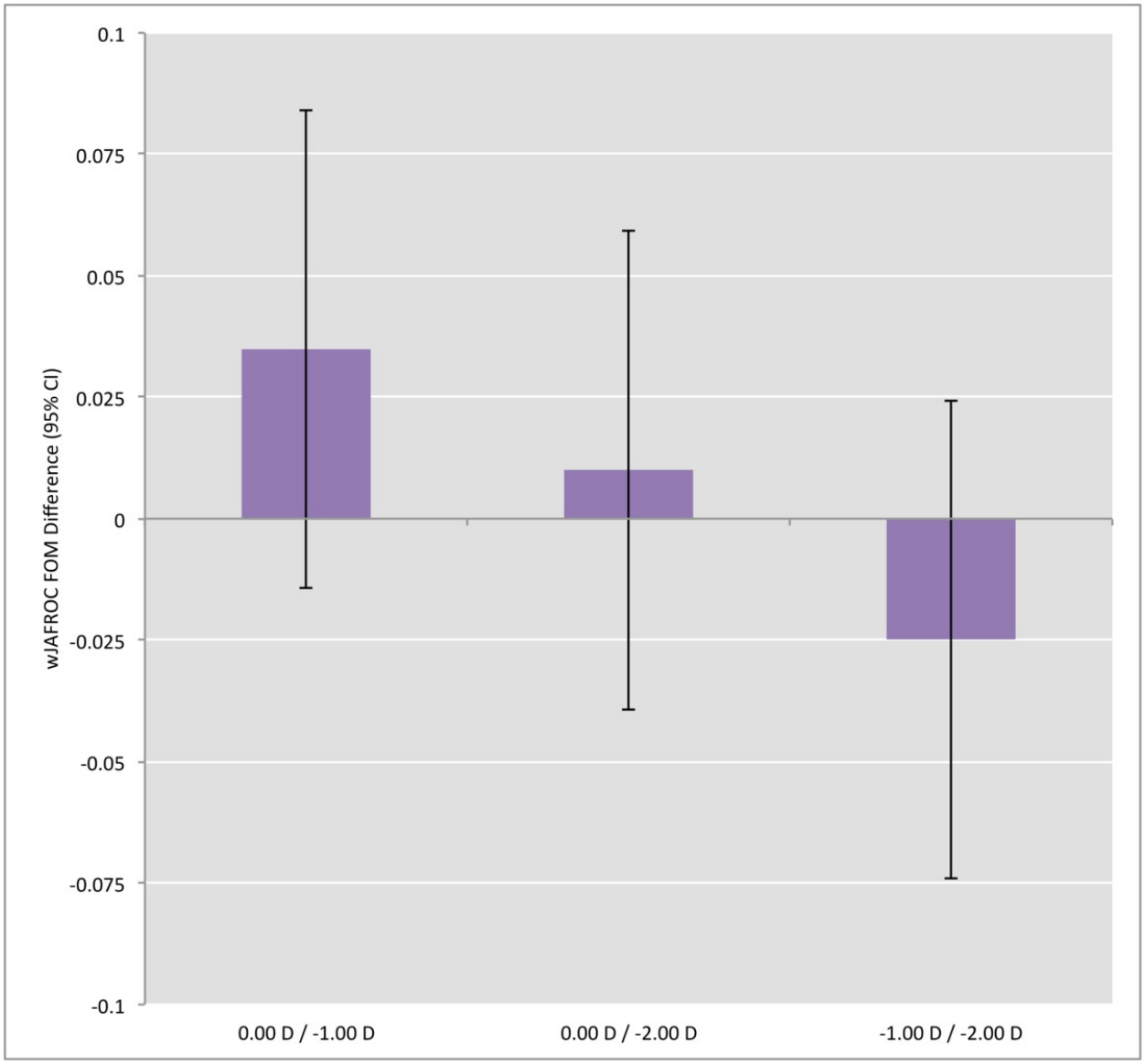

Fig. 3: The inter-treatment differences for all treatment pairs. For a difference to be declared significant, the 95% confidence interval of the treatment pair must not contain zero and the p value of the overall F-test must be less than 0.05. No significant differences observed in this study.

Conclusion

We found no statistically significant difference in nodule detection performance when reducing visual acuity.

Personal information

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