Title: Effect of expertise and contralateral symmetry on the eye movements of observers while diagnosing Pneumoconiosis

Authors:

Varun Jampani*, MS, IIIT-Hyderabad, India
Vivek Vaidya, PhD, GE-Global Research, Bangalore, India
Jayanthi Sivaswamy, PhD, IIIT-Hyderabad, India
Peter Ajemba, PhD , GE-Global Research, India
Kishore LT, MD, Care Hospitals, Hyderabad, India

ABSTRACT

Rationale: Pneumoconiosis[1], a lung disease caused by the inhalation of dust is mainly diagnosed using chest radiographs. It has been shown[12] that expertise and contralateral symmetry (CS) of the chest radiographs plays a significant role in Pneumoconiosis diagnosis. Here, we present a gaze tracking study aimed at understanding how the CS information and the expertise effect the eye movements of observers.

Methods: Experimental subjects consisting of novices, medical students, residents and staff radiologists were presented with 17 double and 16 single lung images, and were asked to give profusion ratings for each lung zone. Eye movements and the time for their diagnosis were also recorded.

Results: Gaze tracking analysis showed that doctors [residents & staff] move eyes more quickly (Mann-Whitney test: U = 20, p = .01) and over more distances (U = 24, p = .022), when compared to that of non-doctors [others]. Wilcoxon signed rank test (Z = 4.19, $p < .001$), revealed that the average time taken for double lung images (*Mdn* = 30808ms) is less than double the time taken for single lung images (*Mdn* = 38385ms). Fixation time for zones correlates well with an observer's certainty in judgment of the same as definitely normal or abnormal. Wilcoxon signed rank test (Z = 3.13, p = .001), showed the less fixation time on the zones of high observer error. Left and right lung gaze transitions correlates well with the observer error only in resident radiologists (r = -0.953, p = .047).

Conclusion: CS information plays a very important role[12] in the case of residents & staff, while diagnosing pneumoconiosis. The present study showed that, for residents, the eye scanning strategies play an important role in using the CS information present in chest radiographs; however, in staff radiologists, peripheral vision or higher level cognitive processes seems to play role in using the CS information.

* **Contact email**: varunjampani@research.iiit.ac.in

RATIONALE

Expertise and contralateral symmetry (CS) in chest radiographs plays a very important role in the diagnosis of pneumoconiosis[2,3,4,6,12]. It has been shown[12] that CS information helps in diagnosing pneumoconiosis by reducing the general tendency of giving less profusion ratings. Its role is more important in doctors [residents & staff radiologists] than in non-doctors. *Training and experience* appear to play important roles in learning to use the CS information present in the chest radiographs.

One of the aims of the present study is to investigate the effects of CS information on the eye movements of observers, while diagnosing chest radiographs. Despite the existence of some observer studies[7,8,9,10] on the usefulness of contra-lateral subtraction technique, to our knowledge, there are no empirical studies on the effect of CS information on eye movements of observers. Since CS information has a more role to play in the case of residents and staff radiologists[12], we are more interested in studying the effect of CS information on these two groups of observers.

Another aim of the present study is to do a preliminary study of how the expertise affects the eye movement patterns while diagnosing pneumoconiosis. Some observer studies[13,14,15,16] showed the significant and important role of expertise on the eye movements of observers while diagnosing chest radiographs. Almost all these studies concentrated on localized lung diseases unlike pneumoconiosis, which is a diffused lung disease.

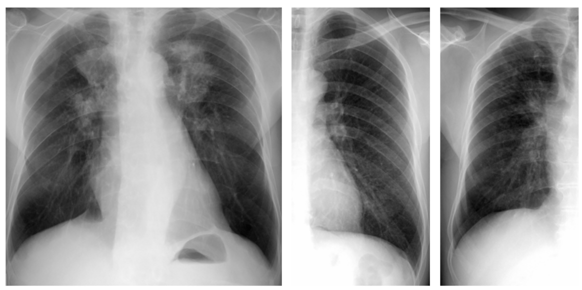

Figure 1: Sample double (left) and single (right) lung images used in the experiment

METHODS

Experimental Setup:

We used remote/head-free eye tracker (Model Eyelink 1000[11], SR research, Canada) to record the eye movements of participants. The test image set consisted of 33 PA digital chest X-rays, of which 17 were normal, full, double-lung images and 16 were single-lung images with only one lung. Figure 1 shows sample single- and double-lung images used in our experiment.

Participant Details:

Experimental subjects varied from novices and undergraduate medical students to expert radiologists. The 23 participants who volunteered for the experiment belonged to 4 categories: staff radiologists (4), resident radiologists (4), medical students (3/yr x 4 yrs = 12) and novices (3). We will, in the course of our discussion, refer to the members of the first two categories put together as *doctors* and the last two as *non-doctors*.

Experimental Procedure:

The entire test set of 17 double and 16 single lung images were shown to each participant, in random order. Each lung region was divided into 3 zones: upper, middle and lower and each participant was asked to report the profusion level of each zone in writing. Prior to the experiment, all the subjects were given training in which the concept of profusion level was explained using some sample chest X-rays. Information such as localization of anomalies, their size and shape are not asked, as the profusion level categorization is of primary importance to clinical settings. Since none of the participants had any expertise in pneumoconiosis, we used 4 levels of profusion categorization rather than 12 levels used in ILO standards[5]: 0 (normal), 1, 2 and 3 (severe). Unlimited time was given to view each image and report profusion ratings. Eye movement data, response times and profusion ratings were recorded for each subject and for each image.

RESULTS

Analysis of eye movement properties:

Figure-2 shows the sample saccade maps (fixation points and transition paths). Mann-Whitney test revealed that the average saccade velocity of doctors (*Mdn* = 142) is significantly higher (U = 20, p = .01) than that of non-doctors (*Mdn* = 123). It has also been showed, by Mann-Whitney test, that the average saccade amplitude is also higher (U = 24, p = .022) for doctors (*Mdn* = 4.68) than that of non-doctors (*Mdn* = 3.98). Thus, doctors seem to be moving eyes more quickly and over more distances, when compared to that of non-doctors.

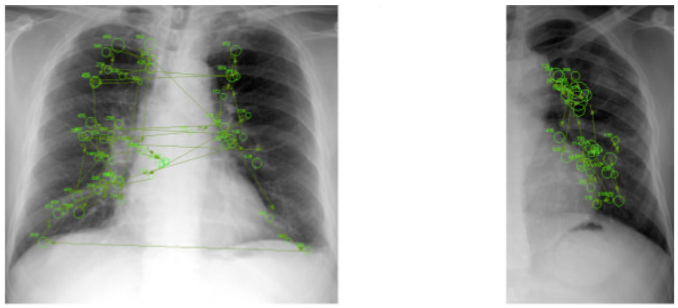

Figure 2: Sample saccade maps showing the eye movements of a participant, recorded while he was viewing (left) a double lung image and (right) a single lung image.

Time Analysis:

Figure-3 shows the average time for diagnosis, for different participant groups. Mann-Whitney test revealed that doctors (*Mdn* = 16688) took less time (U = 21, p = .011) than non-doctors (*Mdn* = 33238) in the diagnosis of double lung images. This is consistent with results of previous studies[16,17] for other anomalies like cancer etc where it was found that experienced viewers are quick and efficient when compared to non-experienced viewers.

When considering all the participants, Wilcoxon signed rank test revealed that, on an average, the time taken for double lung images (*Mdn* = 30838) is less (Z = 4.19, p < .001) than *double* the time taken for single lung images (*Mdn* = 19193). So, it seems that CS information does have effect on the time of diagnosis.

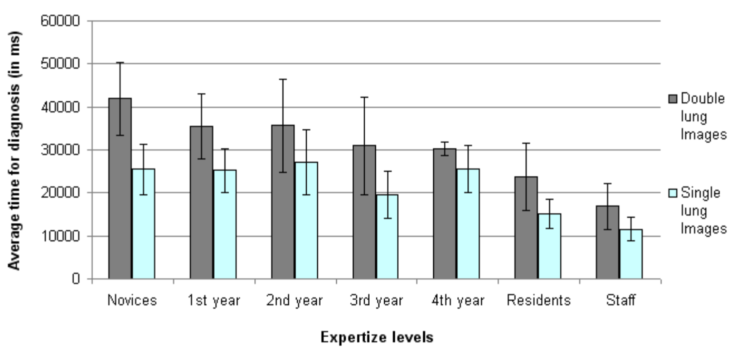

Figure 3: Chart showing the average time (in ms) for diagnosis for single and double lung images and for different expertise groups.

Zonal eye movement Analysis:

In all images (single and double lung images), Wilcoxon signed-rank test revealed that observers' preference order for zones appears to be middle, lower, upper: middle zones (*Mdn* = 0.21) (Z = 5.67, p < .001) than lower zones (*Mdn* = 0.13), (Z = 3.37, p < .001) than upper zones (*Mdn* = 0.10). This might be attributed to the fact that the middle zone has more parenchyma than other zones.

Mann-Whitney test showed that the average percentage fixation time in lung zones with medium observer rating (profusion ratings of 1 and 2) is significantly higher than in the lung zones with extreme ratings (ratings of 0 and 3), in both single lung images (U = 636, p < .001) and in double lung images (U = 556, p < .001). This shows that, whether the image is of single lung or double lung, the zones considered to be clearly normal by the observer (observer rating of '0') and clearly abnormal (3), are less viewed when compared to that of other zones.

Wilcoxon signed rank test revealed that zones with high observer error (absolute error = 3) is less (Z =3.38, p < .001) viewed than zones with medium observer error (2) which are in turn viewed less that zones with low observer errors of both 0 (Z = 2.68, p = .006) and 1 (Z = 2.80, p = .003). No significant relationships between the fixation times are seen between the zones with observer errors of 0 and 1. Thus, in both single and double lung images, zones where the observers made high error are viewed less when compared to that of other less error zones.

Gaze Transitions vs. Performance:

'Gaze transitions' refer to the average number of saccades with their initial position in the left lung region and their final position in the right lung region or vice versa. Only those saccades with difference of less than 50 pixels in y-coordinates of the initial and final fixations are considered. These gaze transitions gives an approximate measure of comparisons made by the observer, between left and right lung regions, by the foveal vision.

Analysis showed a strong correlation (Person's Correlation coefficient, $r = -0.953$, $p = .047$) between gaze transitions and the observer error, in the case of resident radiologists. No such correlation has been found in the case of staff radiologists. This shows the importance of the role of contralateral symmetry in the case of resident radiologists. Even though, CS seems to play an important role in the case of staff also, there is no significant correlation between their gaze transitions and observer error.

CONCLUSION

Analysis of eye movements indicated that, in both single and double lung images, middle zones are most viewed and; doctors move eyes more quickly and over large distances when compared with non-doctors. This is a reasonable result to expect given the fact that doctors have considerably more training and experience, when compared to non-doctors. Less fixation time in the zones which observers think as clearly normal and clearly abnormal, and less fixation time in the zones of high observer error indicates that zones are needed to be looked more carefully even when the observer thinks it as clearly normal or abnormal. In other words, for better diagnostic results, all the zones should be looked carefully i.e. X-rays should not be speed-read.

It has been shown that CS information plays a more important role in the case of residents & staff [12], while diagnosing pneumoconiosis. The present study showed that, for residents, the eye scanning strategies play an important role in using the CS information present in chest radiographs; however, in staff radiologists, peripheral vision or higher level cognitive processes seems to play role in using the CS information.

References:

1. Mason RJ, Murray JF, Broaddus VC, Nadel JA, eds. *Textbook of Respiratory Medicine*. 2005; 4th ed. Philadelphia, Pa: Saunders Elsevier:1758-1763.
2. Morgan RH, Donner MW, Gayler BW, Margulis SI, Rao PS, Wheeler PS. *Decision processes and observer error in the diagnosis of pneumoconiosis by chest roentgenography*. 1973; AJR; 117:757-764.
3. Kruger RP, Thompson W, and Turner A, *Computer diagnosis of pneumoconiosis*, IEEE Trans. Syst., Man, Cybern. 1974; vol. SMC-4, p. 40.
4. Reger RB, Smith CA, Kibelstis A, and Morgan KC, *The effect of film quality and other factors on roentgenographic categorization of coal workers pneumoconiosis*. Amer. J. Roetgenol. Radum Ther. Nucl. Med. 1972; Vol. 115, 462-472.
5. *Guidelines for the use of ILO international classification of radiographs of pneumoconiosis*, 1980. International Labour office: Geneva.
6. Pearson NG, Ashford JR, Morgan DC, Pasqual RSH and Rae S, *Effect of quality of chest radiographs on categorization of coal workers' pneumoconiosis*. British Journal of Industrial Medicine Apr 1965; 22:81-92.
7. Li Q, Katsuragawa S, Ishida T, Yoshida H, Tsukuda S, MacMahon H, and Doi K, *Contralateral subtraction: A novel technique for detection of asymmetric abnormalities on digital chest radiographs,* Med. Phys. 2000; Volume 27, Issue 1: pp. 47-55.
8. Yoshida H and Doi K, *Computerized detection of pulmonary nodules in chest radiographs: reduction of false positives based on symmetry between left and right lungs*, Proc. SPIE. 2000; Vol. 3979: 97.
9. Li Q, Katsuragawa S and Doi K, *Improved contralateral subtraction images by use of elastic matching technique*, Med. Phys. 2000; Volume 27, Issue 8: 1934-1942
10. Tsukuda S, Heshiki A,Katsuragawa S, Li Q, MacMahon H, and Doi K, *Detection of Lung Nodules on Digital Chest Radiographs: Potential Usefulness of a New Contralateral Subtraction Technique*, Radiology. 2002; 223: 199 - 203.
11. http://www.sr-research.com/EL_1000.html
12. Varun J, Vivek V, Jayanthi S and Kishore T, *Role of expertise and contralateral symmetry in the diagnosis of pneumoconiosis: an experimental study*, Proc. SPIE 2011, Vol. 7966, March 2011.
13. Kundel HL, and Nodine CF. *Interpreting chest radiographs without visual search*. Radiology 116:527-532,1975.
14. Kundel HL, and Paul SL Follette. *Visual search patterns and experience with radiological images*. Radiology 103:523-528, 1972.
15. DE Valk, Eijknam. *Analysis of eye fixations during the diagnostic interpretation of chest radiographs*. IFMBE, 353-360, 1984.
16. Christensen EE, Murrry RC, Holland K, and Reynolds J. *The effect of seach time on perception*. Radiology 138:361-365, 1981.
17. Oestmann JW, Greene R, Kushner DC, and Bourgouin PM. *Lung Lesions: Correlationg between viewing time and detection*, Radiology. 1988; 166:451-453.