Visualising scanning patterns of pathologists in the grading of cervical intraepithelial neoplasia

E S M Tiersma, A A W Peters, H A Mooij, G J Fleuren

Aim: To investigate how effectively eye tracking devices can visualise the scanning patterns of pathologists, for application in studies on diagnostic decision making.

Methods: EyeCatcher, an eye tracking device, was used to visualise and compare the scanning patterns of five pathologists while they graded two projections of cervical intraepithelial neoplasia. Density cloud images were created from the scanning patterns. A questionnaire and interview provided information on the following steps in the diagnostic process.

Results: EyeCatcher successfully registered the scanning patterns of the pathologists. A “scanning style” and a “selective style” of visual search were distinguished. The scanning patterns, in addition to the interpretation and combination of the information ultimately leading to a diagnosis, varied between the various observers, resulting in a broad range of final diagnoses.

Conclusions: Eye gaze tracking devices provide an excellent basis for further discussion on the interpretation and grading criteria of lesions. As such, they may play an important role in studies on diagnostic decision making in pathology and in the development of training and quality control programmes for pathologists.

METHODS

The eye gaze tracking system, EyeCatcher, used in our study uses infrared light reflections from the eye. Five pathologists experienced in the histopathological grading of CIN were asked to grade two CIN lesions while wearing a light weight helmet. The pathologists sat in front of a screen displaying successively two images of the CIN lesions (figs 1 and 2). The helmet was mounted with an infrared camera and an infrared light source, a mirror for reflection of the infrared light, and a miniature video camera (fig 3). The infrared light was reflected by the mirror on to the eye and consequently, by way of the eye and mirror, into the infrared camera. Given that infrared light is not visible to the human eye, the pathologists were unaware of the light beam.

This video image of the eye showed the position of the pupil and the location of the “hot spot”. The hot spot is the cornea’s reflection of the infrared light beam. From these two features, the computational part of the system determined the orientation of the eye in relation to the head. The miniature video...

Abbreviations: AFIP, Armed Forces Institute of Pathology; CIN, cervical intraepithelial neoplasia; HPV, human papillomavirus
camera was focused on the projection of the CIN lesion and the video image coming from the camera moved in synchronisation with the pathologist’s head.

The data representing the eye orientation were merged with the images from the miniature video camera. Thus, a video image of the CIN lesion was obtained with a pair of cross hairs indicating the points of gaze in time.

The video images and eye orientation data in digital form were used in a computer analysis to calculate the X and Y coordinates of the points of gaze of the pathologists. Using these coordinates, a graphic representation of the scanning pattern was created in which dots represented the points of gaze every 20 milliseconds. These graphics were blurred using a mathematical calculation to obtain density clouds representing the total amount of attention for each area. By use of colours, areas of high attention were highlighted.

In a briefing beforehand, the pathologists were presented with the Armed Forces Institute of Pathology (AFIP) criteria for the grading of CIN and were requested to grade only according to these descriptions.

Each pathologist was assigned 45 seconds to grade the lesion and was requested to say “yes” as soon as he had reached a diagnosis. At 45 seconds, the CIN projection was covered and the pathologist was asked to answer several questions concerning the interpretation of the projected lesion. The same procedure was repeated for the second CIN lesion.

Afterwards, the pathologists were asked to comment on the test, criteria, and diagnoses during a structured interview.

With regard to the three levels in the diagnostic process, the EyeCatcher was used to register the first step, the scanning pattern, whereas the questionnaire and interview provided information on the next two steps, the interpretation and combination of the information, particularly with regard to the respective grading criteria.
This direct way of looking is most apparent for pathologist 4, who took only seven seconds to gather the information for diagnosis in a highly selective manner.

**Lesion 2**

All pathologists needed more time to reach a diagnosis for lesion 2 than for lesion 1. For all pathologists except pathologist 3, more green/red areas are present in the graphics for lesion 2 than for lesion 1, which means that for lesion 2 the attention was more equally spread over the entire image. In lesion 2 as a whole, more blue areas are present in the graphics in accordance with the longer diagnostic time.

Pathologists 1, 3, and 4 showed more or less the same direct way of looking at lesion 2 as at lesion 1, whereas pathologist 3 showed special attention to the higher regions of the image.

**Registration of the order of the scanning procedure**

The order in which the images were analysed can be studied by connecting the points of gaze in time. The structures of the scanning patterns of the five pathologists often exhibited noticeable differences. Figure 5 shows a clear example of two different structures of the scanning patterns of pathologists (1 and 4) looking at lesion 2.

The eye gaze of pathologist 1 was initially directed at the bottom of the lesion, then moved up to the surface and subsequently slowly moved down again with mostly horizontal movements. Pathologist 2 showed a tidy structure of both horizontal and vertical movements. The movements of the eye gaze below may indicate a quick scanning of the basement membrane.

**Interpretation and diagnostic decision making**

As shown in table 1, the highest variation in the interpretation of the criteria was found for the level of nuclear atypia and the level of abnormal maturation. The answers concerning the mitotic activity did not vary; whereas the answers concerning the atypical character of the mitoses varied for both lesions (data not shown). For lesion 1, all pathologists but one reported the presence of atypical mitoses. Pathologist 2 refrained from answering. For lesion 2, only pathologists 3 and 4 reported the presence of atypical mitoses.

On three occasions, the final diagnosis was not reached in accordance with the AFIP criteria. One of the pathologists graded lesion 1 as CIN 3, although he reported the presence of abnormal maturation, nuclear atypia, and mitoses limited to no more than two thirds of the epithelium. Another pathologist graded lesion 1 as CIN 2, although reporting the presence of abnormal maturation and nuclear atypia extending to three thirds of the epithelium. The same pathologist graded lesion 2 as CIN 1 in the presence of nuclear atypia in three thirds of the epithelium.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Interpretation and diagnostic decision making for lesions 1 and 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pathologist</td>
<td>Time until diagnosis (sec)</td>
</tr>
<tr>
<td><strong>Lesion 1</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>2†</td>
<td>45</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>5†</td>
<td>28</td>
</tr>
<tr>
<td><strong>Lesion 2</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>18</td>
</tr>
<tr>
<td>2</td>
<td>45</td>
</tr>
<tr>
<td>3</td>
<td>32</td>
</tr>
<tr>
<td>4</td>
<td>26</td>
</tr>
<tr>
<td>5</td>
<td>31</td>
</tr>
</tbody>
</table>

Order of criteria: A, proliferation→nuclear atypia→mitotic activity→basement membrane; B, proliferation→mitotic activity→nuclear atypia→basement membrane; C, nuclear atypia→proliferation→mitotic activity→basement membrane; D, nuclear atypia→mitotic activity→proliferation→basement membrane.

*Up to X/3 of the epithelium involved; †diagnosis in discordance with Armed Forces Institute of Pathology criteria.

CIN, cervical intraepithelial neoplasia.
DISCUSSION
We found that the pathologists studied the CIN lesions in different ways, with regard to the areas they examined, the amount of study time for each area, and the order in which the areas were studied. The amount of time needed to reach a diagnosis also varied considerably.

Two types of scanning patterns were distinguished. First, a scanning type of search whereby the pathologists focused on many points within the image but only for a short moment. Second, a selective type of search whereby the pathologists limited their search to specific points within the lesion which they studied for a relatively long time. The differences in scanning patterns between the pathologists were remarkable, especially considering the fact that all pathologists were requested to grade according to the same criteria.

The judgement of the levels to which abnormal proliferation and nuclear atypia were present varied considerably. Most of the questions raised by the pathologists in the questionnaire and interview concerned the interpretation of the level to which nuclear atypia was present, in addition to the extent to which it should influence the final diagnosis. The AFIP states that if pronounced nuclear atypia is noted in the presence of normal maturation in the same layer of the epithelium, and if this nuclear atypia is not the kind of atypia associated with productive human papillomavirus (HPV) infection, the CIN level should be upgraded. However, most pathologists found it difficult to follow this advice, especially during their judgement of lesion 2. They doubted whether the nuclear atypia was HPV related and whether the nuclear atypia was substantial enough to upgrade the CIN level. This was the reason for the large variation in diagnoses for lesion 2.

“The broad range of diagnoses found is especially remarkable because only one selected image was shown for each case”

Studying the density cloud images one can speculate to a certain extent about the criteria studied in the specific areas for both lesions. In lesion 1, the mitotic figure in the middle is obviously a very recognisable criterion. In lesion 2, more red/green areas are present in the graphics. This indicates that the amount of time needed to reach a diagnosis also varied considerably.

The scanning patterns, in addition to the interpretation and combination of the information ultimately leading to a diagnosis, varied between the various observers, resulting in a broad range of final diagnoses. The scanning patterns, in addition to the interpretation and combination of the information ultimately leading to a diagnosis, varied between the various observers, resulting in a broad range of final diagnoses.

Hypothetically, the wide spread in diagnoses found in our study may arise from the differences in scanning patterns. However, the different scanning patterns are probably a reflection of differences in the way the images were interpreted and the way the grading criteria were applied by the pathologists. By showing the areas of high attention during the visual search by the pathologist, eye tracking devices provide an excellent basis for further discussion on the interpretation and grading criteria. Eye tracking devices as such may be a valuable asset in pathology, for detailed studies on diagnostic decision making, in addition to the development of training and quality control programmes for pathologists.

ACKNOWLEDGEMENTS
We are indebted to M Witjes for his technical help and to H van Krieken, F van Kemenade, M van de Vijver, J Calame, M Veselic, and K van Leeuwen for their participation in the experiment.

Authors’ affiliations
E S M Tiersma, A W Peters, Department of Obstetrics and Gynaecology, Leiden University Medical Centre, Postbus 9600, 2300 RC Leiden, The Netherlands
H A Mooij, G J Fleuren, Department of Pathology, Leiden University Medical Centre

REFERENCES
1 Kundel HL, Nodine CF, Krupinski EA. Searching for lung nodules: visual dwell indicates locations of false-positive and false-negative decisions. Invest Radiol 1989;24:472–8

Take home messages
• EyeCatcher distinguished two scanning patterns in the five pathologists: a “scanning style” and a “selective style” of visual searching.
• The scanning patterns, in addition to the interpretation and combination of the information ultimately leading to a diagnosis, varied between the various observers, resulting in a broad range of final diagnoses.
• Eye gaze tracking devices could play an important role in studies on diagnostic decision making in pathology and in the development of training and quality control programmes for pathologists.
Visualising scanning patterns of pathologists in the grading of cervical intraepithelial neoplasia

E S M Tiersma, A A W Peters, H A Mooij and G J Fleuren

doi: 10.1136/jcp.56.9.677

Updated information and services can be found at:
http://jcp.bmj.com/content/56/9/677

These include:

**References**
This article cites 10 articles, 4 of which you can access for free at:
http://jcp.bmj.com/content/56/9/677#BIBL

**Email alerting service**
Receive free email alerts when new articles cite this article. Sign up in the box at the top right corner of the online article.

**Topic Collections**
Articles on similar topics can be found in the following collections

- Cervical cancer (80)
- Cervical screening (52)
- Gynecological cancer (184)

To request permissions go to:
http://group.bmj.com/group/rights-licensing/permissions

To order reprints go to:
http://journals.bmj.com/cgi/reprintform

To subscribe to BMJ go to:
http://group.bmj.com/subscribe/