Elizabeth A. Krupinski, PhD ▮ Harold L. Kundel, MD ▮ Philip F. Judy, PhD ▮ Calvin F. Nodine, PhD

The Medical Image Perception Society

Key Issues for Image Perception Research[1]

The Medical Image Perception Society (MIPS) is an international society that was organized in 1997 to promote research and education in medical image perception and to provide a forum for the discussion of perceptual, psychophysical, and cognitive issues by radiologists and basic scientists. It developed as an outgrowth of the Far West Image Perception Conference, which has met biennially since 1983.

The goals of perception research have been outlined at a number of conferences and workshops (1). Broadly, they include (*a*) mathematical modeling of the detection of discrete abnormalities in noise-limited images, (*b*) understanding how observers find discrete abnormalities in images when their locations are unknown, (*c*) understanding how knowledge and experience affect the recognition and detection of abnormalities, (*d*) developing perceptually based standards for image quality, (*e*) developing computer-aided perception tools, and (*f*) developing quantitative methods for describing natural images and for measuring human detection and recognition performance.

Index terms:
Computers, diagnostic aid
Images, display
Images, interpretation
Images, quality
Radiology and radiologists, research
Subspecialty society messages

Radiology 1998; 209:611–612

[1] From the Department of Radiology, University of Arizona, Tucson (E.A.K.); the Department of Radiology, University of Pennsylvania, 3400 Spruce St, Philadelphia, PA 19104 (H.L.K., C.F.N.); and the Department of Radiology, Brigham and Women's Hospital, Boston, Mass (P.F.J.). Received June 17, 1998; accepted June 19. **Address reprint requests to** H.L.K.

See also the article by Potchen (pp 613–614) in this issue.

Modeling the Detection Task

One of the important properties of most medical images is that noise is visible at the luminance levels used for viewing. As a consequence, noise limits the perception of contrast and detail. A great deal of research has been done on mathematical models that relate signal detection to physical descriptions of image signal and noise (2). Robust models have been developed for the detection of simple objects embedded in backgrounds of statistically defined noise (3). Most of the objects are small relative to the size of the background, and they are selected to have features in common with real lesions such as breast masses and microcalcifications or lung nodules and interstitial fibrosis. When the background consists of a natural medical image such as a chest radiograph (4) or a computed tomographic image of the liver (5), the models are not as good at predicting performance. Current research is extending the models to include realistic lesions and anatomical backgrounds (6). This requires exact knowledge of the physical properties of abnormalities and backgrounds. The development of this knowledge is being approached by using real images and synthesizing both abnormalities and anatomical backgrounds.

Understanding Visual Search

Studies of target detection in the laboratory generally begin by informing the observer about the location of the target under study. In the real world, the target is a real lesion with a location that is known only approximately. For example, when the target is a lung nodule, the observer knows where nodules are likely to hide in the lungs; or, when the target is a fracture, the observer may be told that there was trauma to the hand or to the ribs. Many lesions can be seen by peripheral vision and verified by foveal vision, but peripherally inconspicuous targets must be found by scanning the fovea over the image. The resultant search pattern, as shown by eye-position recording, is influenced by both clinical history (7,8) and experience (9,10). The phenomenon known as satisfaction of search (11,12), in which the detection of inconspicuous abnormalities is degraded in the presence of unrelated abnormalities, has been well demonstrated but is not fully understood.

Understanding the Nature of Expertise

The few objective studies of image reading that have been done show that imaging specialists perform better than imaging generalists, who perform better than general physicians. The factors that lead to such expertise are not well understood. If they were, we would be able to do a better job of making ordinary people into experts. The nature of expertise can be broadly divided into knowledge and experience (9,13). Perception research that focuses on the observer can expand our understanding of how knowledge gained from training and supplemented by experience influences diagnostic performance. Research can also clarify situations in which errors (missed diagnoses) occur and identify when they are a consequence of fundamentally ambiguous information rather than problems of perception, attention, or decision making.

Developing Perceptually Based Standards for Image Quality

Medical imaging is moving toward the widespread use of digital image acquisition and associated computer-driven soft-copy displays. The same versatility that makes displaying images on soft copy desir-

able also makes it possible for different observers to see the image data from different perspectives. There is a need to determine the optimal presentation parameters (eg, size, luminance levels, and spatial and contrast resolution) and to develop display standards so that all observers have the opportunity to see the same image presentation (14). Image quality is a subjective judgment made by technologists and radiologists on the basis of a community consensus. It would be very useful to have objective criteria for image quality based on the diagnostic performance of observers.

Developing Aids to Image Perception

Digital imaging also opens up the possibility of modifying the image in ways that improve the perception of abnormalities and of using computer aids to identify potentially abnormal regions either by image analysis by using computer-assisted diagnosis (CAD) (15) or by monitoring observer behavior by using computer-assisted visual search (CAVS) (16). Part of the problem with implementing computer aids in the clinical environment is that only a few limited studies have been conducted to demonstrate reliably their usefulness in improving detection performance. Developing ways to examine the influence of CAD and CAVS on perception and decision making in the clinical environment will help confirm their usefulness as clinical tools.

Methodological Studies

Describing the stimulus.—Perceptual studies often start by using phantoms containing physical objects that have features similar to natural abnormalities as test objects. Psychophysical studies of the perception of prototypical signals against backgrounds of Gaussian noise have progressed to the use of more complex "lumpy" backgrounds and are moving toward descriptions of realistic signals embedded in natural image backgrounds. Anthropomorphic phantoms that mimic the body may contain real organs such as lungs and bones, but they are restrictive because they produce unvarying backgrounds, whereas natural backgrounds are variable. At present, synthesized lesions can be grafted into natural backgrounds to produce hybrid images. There is a need to develop methods for producing synthetic backgrounds that have properties similar to natural images. This will provide investigators with a large supply of images with marginally detectable lesions that have known locations. It will also aid in understanding the mathematical properties of real backgrounds.

Describing the response.—The receiver operating characteristic (ROC) analysis and the forced-choice methodology that was introduced into radiology from engineering and perceptual psychology have become the mainstays of performance measurement. The ROC analysis and the associated forced-choice methodology have limitations that preclude their use in many clinical situations where objective evaluation is needed. They are labor-intensive and their decision method, which uses rating scales or yes-no alternatives, does not resemble the way that images are read and decisions are made in the clinical environment. Additionally, neither method can adequately handle case samples where there are multiple abnormalities or where independent proof of the diagnosis cannot be obtained. Alternative methods to quantitatively evaluate diagnostic performance are needed.

How Radiology Benefits from Research in Image Perception

Perception research will benefit clinical radiology by providing methods for reducing observer error, providing objective standards for image quality, and providing a scientific basis for image-technology evaluation.

At least half of the errors made in clinical practice are perceptual (17,18). The entire research effort in CAD is an attempt to catch these errors by dual reading. It would be more satisfying to understand the perceptual process well enough to catch them right from the start.

Perceptually derived models are powerful because they can be used to predict human performance and because human performance can be compared to an ideal observer who has complete knowledge about the image. The relationship between the performance of the human and the ideal observer is an indication of how much room there is for improvement in the observer. In addition, predictions can be made about the effect of changes in imaging system parameters on diagnostic performance without having to resort to expensive and time-consuming observer tests. As it is, every new method of processing or displaying the image either has to be accepted blindly or tested laboriously.

Visual scientists working in radiology have made considerable progress in modeling detectability, describing visual search, and developing robust methodologies. MIPS was organized as a forum where concerned scientists and clinicians can freely discuss problems and progress.

References

1. Kundel HL. Medical image perception. In: Holman LB, Edwards SH, eds. Developing a long-term plan for imaging research. Acad Radiol 1995; 2 (suppl):108–110.
2. Wagner RF, Brown DG. Unified SNR analysis of medical imaging systems. Phys Med Biol 1985; 30:489–518.
3. Burgess A. Statistically defined backgrounds: performance of a modified nonprewhitening matched filter model. J Opt Soc Am 1994; 11:1237–1242.
4. Kundel HL, Nodine CF, Thickman DI, Carmody DP, Toto LC. Nodule detection with and without a chest image. Invest Radiol 1985; 20:94–99.
5. Seltzer SE, Swensson RG, Nawfel RD, Lentini JF, Kazda I, Judy P. Visualization and detection-localization on computed tomographic images. Invest Radiol 1991; 26: 285–294.
6. Eckstein M, Whiting J. Lesion detection in structured noise. Acad Radiol 1995; 2:249–253.
7. Berbaum KS, Franken JEA, Anderson KL, et al. The influence of clinical history on visual search with single and multiple abnormalities. Invest Radiol 1993; 28:191–201.
8. Kundel HL, Wright DJ. The influence of prior knowledge on visual search strategies during the viewing of chest radiographs. Radiology 1969; 93:315–320.
9. Krupinski E. Influence of experience on scanning strategies in mammography. In: Kundel H, ed. Medical imaging 1996: image perception. Proc SPIE 1996; 2712:95–101.
10. Kundel HL, LaFollette PS. Visual search patterns and experience with radiological images. Radiology 1972; 103:523–528.
11. Samuel S, Kundel HL, Nodine CF, Toto LC. Mechanism of satisfaction of search: eye position recordings in the reading of chest radiographs. Radiology 1995; 194:895–902.
12. Berbaum KS, Franken JEA, Dorfman DD, et al. Role of faulty visual search in the satisfaction of search effect in chest radiography. Acad Radiol 1998; 5:9–19.
13. Nodine CF, Kundel HL, Lauver SC, Toto LC. Nature of expertise in searching mammograms for breast masses. Acad Radiol 1996; 3:1000–1006.
14. Seltzer SE, Judy PF, Feldman U, Scarff L, Jacobson FL. Influence of CT image size and format on accuracy of lung nodule detection. Radiology 1998; 206:617–622.
15. Nishikawa RM, Giger ML, Doi K, Vyborny CJ, Schmidt RA. Computer-aided detection of clustered microcalcifications: an improved method for group detected signals. Med Phys 1993; 20:1661–1666.
16. Nodine CF, Kundel HL. Computer assisted perception aids pulmonary nodule detection. In: Kundel H, ed. Medical imaging 1994: image perception. Proc SPIE 1994; 2166:55–58.
17. Renfrew DL, Franken JEA, Berbaum KS, Weigelt FH, Abu-Yousef M. Error in radiology: classification and lesions in 182 cases presented at a problem case conference. Radiology 1992; 183:145–150.
18. Bird RE, Wallace TW, Yankaskas BC. Analysis of cancers missed at screening mammography. Radiology 1992; 184:613–617.