Supplementary Materials: Interviews with Expert Searchers

BOX 1. Interview with a Radiologist: Harold Kundel, Professor Emeritus, University of Pennsylvania

Harold L. Kundel, MD is a diagnostic radiologist and is currently the Professor Emeritus of Radiology at the University of Pennsylvania. His research interests are in understanding image reader performance, using human performance for the evaluation of imaging technology and the development of decision aids for radiologists. He was among the first investigators in radiology to use receiver operating characteristic (ROC) ROC analysis for technology evaluation. He has used the ROCanalysis for the evaluation of a variety of imaging techniques ranging from television and digital image processing to display stations for use with picture archiving and communication (PACS) systems. Together with psychologist Calvin F. Nodine, he developed gaze tracking methodology for studying errors of lung nodule detection.

What are the main perceptual and search strategies that make for a "great performing"radiologist?

I divide imaging skills into two components, perceptual and interpretation. The radiologist has to see what is on the image and determine what it means. Let me illustrate my point with an anecdote:

At Temple University we had a daily noon conference where residents and sometimes staff showed interesting and instructive cases. The standard procedure was to describe the findings and then give the interpretation. During the year it was possible to follow the development of the residents' skill at this game. Some residents saw what was on the image very quickly and very early in their training. They also were usually best at interpretation. Others developed their ability to describe findings and find subtle abnormalities more slowly, taking weeks to months. It always seemed to me that the early starters made the best radiologists in the end although I could not prove it. It also suggests to me that there are people whose innate pattern recognition capability is better than others. A friend of mine who was the principal of an elementary school could recognize and name all of the few hundred children in the school. The "*great performing radiologist*" is one who quickly recognizes and names abnormalities on images. What do I mean by quickly? A few seconds – or about as long as it takes for you to recognize your grandmother. How is it done? I do not know.

What does experience give the expert radiologist that the starting radiologist does not have?

Experience has a number of components. First, actually interpreting cases is of paramount importance. However just reporting cases is not enough. There must be feedback about success and failure. This unfortunately is difficult to achieve without a close relationship to clinical colleagues. Second, it is necessary to build up a body of understanding of the manifestations of disease as revealed in images. Didactically this is done by showing proved cases and ideally by showing anatomical and pathological

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specimens with them. The teaching objectives of the Temple Noon Conferences which was a major part of the residency program when I was there consisted of: 1) showing the usual manifestations of common diseases, 2) the unusual manifestations of common diseases, 3) the usual manifestations of rare or unusual diseases. Practically, it again requires getting involved with clinical colleagues. While developing the PACS (Picture Archival Computer System) system, I had the opportunity to review the chest images and to find out how the clinicians conceptualized the patient's disease and management. Many of my colleagues believe that reading the journals is a good way to build up the body of knowledge about the manifestations of disease in images. I regard this as a secondary component, one step removed from practical experience. I always used my reading time to try to increase my understanding of a particularly perplexing case or follow up on an interesting case. I have always tried to relate my reading of the texts and journals to what I was doing in practice.

What are the most common mistakes radiologists make that lead them to incorrect diagnostic decisions?

In 1967, Marcus Smith a radiologist in private practice in New Mexico wrote a book called "Error and Variation in Diagnostic Radiology". He compiled and classified 437 errors that he made during a 2 year period. Tony Franken's group produced a modern version of Smith's data and found that perceptual errors dominated (Renfrew et al., 1992).

How much variation is there in perceptual performance across different radiologists?

A lot. The classic source is Garland (1949) who reported inter-individual disagreement of 34 to 49 percent and intra-individual disagreement of 17 to 33 percent. I generally refer to two more recent sources that sadly do not show much improvement (Beam et al., 1996; Potchen et al., 2000).

How much does a radiologist's perceptual performance vary across her/his career?

I do not know. No data available. A guess: not much.

Do radiologists adopt their particular idiosyncratic strategies that they use throughout their career? Might you give some examples?

Again I have no evidence but some anecdotal observations. If search strategies are reflected in the visual scanpaths adopted when searching images rich in structure, then some changes can be found as the career matures. By rich in structure, I refer to something like a plain chest radiogram as opposed to a mammogram. The patterns of medical students change markedly after they have learned about pathology. As radiologists begin to sub-specialize their scanpaths also change (Kundel and LaFollete, 1972).

What in your opinion could be made to improve radiologists overall diagnostic decision accuracy?

1. Impeccable radiographic technique – Too many radiologists accept sloppy technique.

2. Double reading - Although it is still controversial, I believe that *independent* double reading with some logical method of conflict resolution improves performance. In a sense Computer Assisted Diagnosis is an independent second reading. It is not yet good enough to match a human second

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reader.

3. Develop a systematic method for viewing and reporting studies and learn to stick with it. I used to first look at the images and make a decision. Then I would read the "clinical information", which I realize is sometimes wrong and re-evaluate my decision while looking at the images. Finally I would report the case in a systematic way structuring my report anatomically and looking at each anatomic region as I spout the words. Structured reporting has never been popular but I believe that it can improve performance by forcing the reader to be complete.

4. Follow up cases. Try to find out what happened to the patient and whether the report was correct or useful (i.e.. cultivate collaborative relationships with the clinicians).

References:

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BOX 2. Interview with a Satellite Image Analyst with 25 + years experience (Anonymous)

This interview was facilitated by the National Geospatial Agency and conducted via email. The interviewed satellite image analyst has 25+ years experience having searched thousands of frames.

What are the main perceptual and search strategies that make for a "great performing" satellite analyst?

Target knowledge is the single most important factor. Knowing what things look like in your part of the world saves lots of time in terms of minimizing time spent researching strange things you may come across. Recognizing targets or potential targets quickly saves time. Understanding where things are "supposed to be" helps you search faster - concentrating on areas most likely to produce results and minimizing the amount of time spent on areas less likely to be productive. Understanding the spatial relationships between related things (similar or related targets) also alerts an intelligence analyst when something is "missing" and may cause him/her to spend more time looking for it (i.e., search until you find it, or determine that it just is not there). Acquiring target knowledge is a function of how many targets/images you have looked at (both of the region in question and other images in other areas that have similar features). Experienced IAs search faster, find more, and miss less than less experienced analysts mostly because they have brains populated with thousands of images and tens of thousands of targets looked at over time (and from a wider variety of viewing perspectives). Also, intelligence analysts who do search conducted as an integral part of their regular job consistently outperform people who do it less frequently or as an added duty. "Search days" once or twice a month do not yield results comparable to having people search every day for an extended period.

What does experience give the expert satellite image analyst that the starting analyst does not have?

See #2 above. Also, the more issues and regions an intelligence analyst has worked, the more frames of reference he can bring to bear on any one of them or to a new one. Each image looked at is being compared (subconsciously) to every other frame an analyst has ever looked at in the past. The more images, the more frames of reference.

What are the most common mistakes analysts make that lead them to incorrect decisions?

Lack of experience/target knowledge for some types of targets (no one is familiar with everything). Someone used to looking at one type of military target all day may not recognize a small military target of another type or a particular type of industrial facility or may not understand its significance. Someone unfamiliar with a particular type of target may not know to look for the other targets that may be associated with it or where to look to find them.

Does fatigue and loss of concentration (attention) play a role in making mistakes?

Yes, but not as much as you might think. Interruptions and distractions also contribute to errors.

How much variation is there in search and interpretation performance across different analysts?

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Quite a bit. Analysts who do search more frequently, enjoy doing it, and have a broader and deeper understanding of the target set are much better at it than novices who do it infrequently, hate doing it, and don't have much context to bring to bear.

How much does an analyst's performance vary across her/his career?

Performance increases with the amount of time spent doing search and in doing imagery analysis in general.

Do analysts adopt their particular idiosyncratic strategies that they use throughout their career? Might you give some examples?

I'll give you two answers to this one:

1) Yes. Some immerse more fully in the imagery; "get into the zone;" become "one with the image". Sometimes headphones/music are an integral part of this. Sometimes special light conditions or monitor settings are involved. Some analysts clear their schedules so they can do it without interruption. For them, search is done to the exclusion of everything else; lunches are skipped or delayed; bathroom breaks are put off as long as possible; other activities are not engaged in; even minor interruptions are major annoyances. An analyst gets so deeply into the image that he becomes engulfed by it. I once heard of a guy making train noises while doing search along a rail line.

2) Aside from idiosyncratic strategies, there are also methodological ones. These are also very important and these have changed a great deal, not always for the better, since we have moved from hardcopy exploitation to softcopy.

What in your opinion could be made to improve analysts' overall decision accuracy?

Better tools that permit a range of methods and techniques to be used. Better search training that presents an array of methods and techniques along with the situations where each might be most effective. Tools that simplify the process, facilitate (or automate) iterative functions, and permit adaptations to methods and techniques would all help.

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Box 3. Interview with a fisherman/watchman from Pampatar, Margarita Island, Venezuela: Ramon "Moncho" Labori.

Description of the visual task: The watchman's job is to sit on a hill which allows him a good view of the ocean and to inspect the sea surface to identify whether the school of fish is present. After identifying the school, the watchman signals to the fishermen on the beach the location and type of fish present (which determines the thread of the net used to catch the fish). The fishermen on the beach proceed with their boats to catch the fish.

What makes a good watchman?

To be a good watchman it takes about 3-4 years. Don't think that it is easy to become one. You first look at the experts to see the way they do it and learn.

How do you visually identify the presence of a school of sardines from the hill?

When a school of sardines comes far away, one cannot distinguish the redness of the sardines on the ocean surface, but one can notice it because the birds dive onto the fish and one concentrates on that spot where the bird dives and then one can really see the redness of the spots, on the ocean surface. The bird indicated where it is and any shadow you see, there, and then, you can identify the sardine.

Is there anything aside from the spot on the ocean that indicates the presence of the school of sardines?

The bird. And if the water is dark then you cannot see the redness. Then, where you see the bird you can send a diver to see whether there are in fact sardines there or not.

What can be in the ocean that can make you think that there are sardines when they are not there?

Algae and seaweed, all of those can be confused with the school of sardines, it gives the same color as the school of sardines.

There are also stones that can give rise to a spot on the ocean that mimics that of the sardines? What about these?

Well, one has the stones located. One already knows where these stones are from everyday experience so

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one cannot confuse them with the sardine. That spot is that stone, and that other one is that other stone.

Is there another fish that can be confused with the sardines?

The “canalero”. It is long and small. From afar the spot of the “canalero” is similar to the sardine but one can tell them apart because the bird dives in a different way to them.

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