Visual diagnostic reasoning: from theory to practice

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“Clinical reasoning is as difficult to define as it is to teach”

(Linn et al, 2008, Teaching in General Practice 41:1)
15 year old quarter horse mare with a history of recurrent laminitis
Polyuria and polydipsia
Polyphagic
Hyperhidrosis

Laboratory data:
Fasting hyperglycemia and glycosuria
Mild anemia
Lymphopenia
Elevated liver enzymes
Elevated serum ACTH
What is clinical reasoning?

The sum of thinking and decision-making processes associated with clinical practice.

(Higgs, 2008)
The nature of clinical reasoning

- Problems are ill-structured and evidence is ambiguous
  - Decision making needs to occur based on dynamic and ill-defined information
  - Shifting and competing goals and outcomes
- Occurs on action-feedback loops
- Decisions have elements of time-pressure, personal stress and highly significant outcomes for patients

Yet, it is one of the most defining features of expertise and practice excellence.
Research and understanding clinical reasoning

- Complex mostly invisible process
- Automatic and highly attenuated
- Highly individualized
- Requires a range of capabilities:
  - Cognition,
  - Metacognition,
  - Emotion,
  - Reflexive and
  - Social
Diagnostic Reasoning Theories (as a cognitive process)

• Analytical reasoning
  – Hypothetico-deductive
  – Forward and backward reasoning
  – Bayes Theorem

• Non-analytical reasoning
  – Pattern recognition
  – Knowledge structures
  – Script theory

• Dual processing theory
Analytical reasoning

- Hypothetico-deductive reasoning
- Forward and backward reasoning strategies
- Bayes’ theorem
  - Pre- and post-test probabilities and likelihood ratios
  - Errors in frequency estimations:
    - Overestimation of vivid or easily recalled events/Underestimation of ordinary events
    - Overestimation of frequency of events that fit a representative case
    - Probabilities at the extreme (close to 0 and 1) tend to be over and underestimated

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Non-analytical reasoning

- **Pattern recognition** (Patel, Norman, Eva, Groen, Schmidt)
  - Rapid, automatic and non-verbal
  - Experience
  - Automated retrieval knowledge
- **Knowledge structures**
- **Script theory**
Knowledge structures

Type III hypersensitivity

Circulating immune complexes deposit in basement membrane

Complement, humoral and cell-mediated immune cell damage to glomerulus

Increased leakiness of glomerulus approximately same MW as albumin

PROTEINURIA

Antibody-antigen structure and production

Glomerular microanatomy and renal physiology
Knowledge structures

• Causes (Lyme, Babesia, RMSF, Ehrlichia, hepatozoon, Leishmania, CAV-1, Leptospirosis, heart worm, trypanosomiasis, schistosomiasis, GI disease, neoplasia, SLE, hypertension, hyperadrenocortism, juvenile renal dysplasia, congenital glomerulopathy)

• Relative prevalence and likelihood of diagnoses (dependent on animal’s age, breed, location, history, etc.)

• Diagnostic tests that differentiate DDx (expected results, normal reference intervals, acceptable ranges for DDx)

• Possible treatments

• Prognosis
Encapsulation theory

Stage 1: Development of elaborated causal networks
- Relatedness of concepts
- Cause and consequence of pathophysiologic processes

Stage 2: Compilation of elaborated networks into abridged ones
- Extensive and repeated application
- High level simplified causal models using diagnosis to explain signs and symptoms

Stage 3: Emergence of Illness scripts

Stage 4: Storing patient encounters as Instance script

Adapted from Schmidt (1990) Acad Med 65(10):611-621
Script theory
(Schmidt 1990, Charlin 2000, Charlin 2007)

- Illness scripts that are activated by pattern recognition
- Cognitive structures present in experienced clinicians
  - Constructed during repeated experience
  - More efficient task performance
- Hierarchical with “slots” pertaining to:
  - Predisposing conditions
  - Clinical signs
  - Pathophysiology
  - Diagnostic testing
  - Acceptable and not acceptable values
  - Treatment options
  - Prognosis
Analytical reasoning
- Hypothetico-deductive
- Bayes’ theorem
- Forward reasoning
- Backward reasoning

Non-analytical reasoning
- Pattern recognition
- Automated retrieval of knowledge structures
- Script theory
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• Dual processing theory
## Dual process theory of human judgment

(Kahneman 2003, Evans 2008)

System 1 and System 2 reasoning processes in human decision-making

<table>
<thead>
<tr>
<th>Attribute cluster</th>
<th>System 1</th>
<th>System 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consciousness</td>
<td>Unconscious</td>
<td>Conscious</td>
</tr>
<tr>
<td></td>
<td>Implicit</td>
<td>Explicit</td>
</tr>
<tr>
<td></td>
<td>Automatic</td>
<td>Controlled</td>
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<tr>
<td></td>
<td>Low effort</td>
<td>High effort</td>
</tr>
<tr>
<td></td>
<td>Rapid</td>
<td>Slow</td>
</tr>
<tr>
<td></td>
<td>High capacity</td>
<td>Low capacity</td>
</tr>
<tr>
<td></td>
<td>Holistic, perceptual</td>
<td>Analytic, reflective</td>
</tr>
<tr>
<td>Evolution</td>
<td>Evolutionarily old, shared with animals</td>
<td>Evolutionarily recent, uniquely human</td>
</tr>
<tr>
<td>Functional characteristics</td>
<td>Associated</td>
<td>Rule-based</td>
</tr>
<tr>
<td></td>
<td>Contextualized</td>
<td>Abstract</td>
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<tr>
<td></td>
<td>Pragmatic</td>
<td>Logical</td>
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<tr>
<td></td>
<td>Parallel</td>
<td>Sequential</td>
</tr>
<tr>
<td>Individual differences</td>
<td>Independent of intelligence and working memory</td>
<td>Linked to intelligence and limited to working memory capacity</td>
</tr>
</tbody>
</table>

Dual process theory in clinical reasoning

• System 1 default overridden by system 2:
  – Strong deductive reasoning instructions, dissonant patterns, high cognitive ability
• System 1 highly related to experience
  – Repetitive system 2 processing can lead to a system 1 response
• System 2 impaired by stresses on working memory
  – Includes lack of sleep, competing thought processes, emotion, time pressure
• Clinicians use a mixture of intuition and analysis in decision making
• No “better” system—both are necessary and both are involved in diagnostic error
Our understanding of clinical reasoning so far.....

- System 1 and system 2 dual reasoning theories likely accounts for much of the cognitive processes of clinical reasoning
  - Experts with familiar cases tend to use system 1 reasoning
  - Novices tend to use system 2 reasoning
  - Experts are triggered to use system 2 reasoning in unfamiliar cases, cases with dissonant data or as a “checks and balance” to their reasoning
  - Not likely a dichotomy but a continuum with clinicians switching back and forth between system 1 and system 2 reasoning

- Experts possess an extensive and multidimensional knowledge base = SCRIPTS
  - Initial exposure of clinicians to a case typically stimulates initial System 1 retrieval of multiple illness scripts
Veterinary medicine is a visual science
FNA Subcutaneous mass, 6 year old, FS, Rottweiler
When do we use visual reasoning skills?

- Pathology
- Dermatology
- Diagnostic imaging
Sensation and perception

Comparison of image to sensory, short and long term memory
Sensation and perception

Entire scene in peripheral vision, interesting features pop out.

Scene disengaged, foveal attention on area of interest, "Fixation".

Eyes reposition to new area of interest, "Saccade".
Eye-tracking technology

• Eye position represents visual attention
• Fixations and saccades of eye-movement
Visual reasoning hypothesis

• Experts develop sophisticated illness scripts triggered by visual images
• Using eye-tracking we expect that experts have more efficient and targeted viewing of a slide, akin to system 1 thinking
• Experts differ from novices by:
  – Reduced total time which slides are viewed
  – Select more diagnostically relevant fixation points
  – Spend more time on diagnostically relevant fixation points
Novice-expert study

**Dependent variables:**
1. Diagnostic accuracy (dichotomous)
2. Percentage time spent viewing the area of interest
3. Time to diagnosis
4. Eye-movement pattern
5. Talk aloud protocol

Round cell images 1-5 with AOIs
What differences do we see between novice and experts?

1. Experts have a much shorter time to diagnosis

2. Experts spend more time visualizing key features and use more individual key features to make a diagnosis than novices

3. Experts have efficient eye-pattern movements

4. Experts use higher order “knowledge collation” terms

5. Experts had a higher level of diagnostic accuracy
What can we conclude?

Experts employ pattern-recognition (System 1) and

- System 1 reasoning fast, intuitive (quicker to diagnosis)
- More efficient eye-movements

Experts use script inductive reasoning with analytic (System 2) justification

- More diagnostic features identified suggests script induction
- Suggest experts develop a sophisticated set of “visual illness scripts”
Multimodal assessment of visual diagnostic reasoning

• In collaboration with Dr. Kent Hecker
• fMRI showed different levels of activation within novices between hard and easy clinical reasoning scenarios
• System 2 reasoning is localized to the prefrontal cortex neural areas of activation in novice and expert clinicians during clinical reasoning tasks
This is all great..... but what does all this mean in teaching and learning?

Stay tuned for tomorrow!
Acknowledgments

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