Exploring the knowledge base structures enabling physicians to perform differential diagnosis in accordance with Dual Processing Theory

Frank J Papa, DO, PhD
Tiraj Parikh, BS
UNTHSC
Background

- DPT...
  - A theory describing how humans perform categorization tasks involving ill-defined categories
  - Two cognitive systems enable categorization
  - Each system has two distinct components:
    - 1) Information processing/reasoning mechanism(s) which also serves as the characteristic feature of the system, and
    - 2) Knowledge specifically organized/structured to support each system’s characteristic information processing/reasoning mechanism(s).
  - System 1’s information processing/reasoning mechanism ...
    - Rapid, reflexive/autonomous,
    - Pattern recognition/similarity-oriented approach to categorization,
  - System 2’s information processing/reasoning mechanism ...
    - Slower, conscious/deliberate,
    - Analytically-based approach to categorization.
Background

- Accuracy in a categorization task involving ill-defined categories is much more dependent upon the given System’s knowledge rather than upon its information processing/reasoning mechanism.

- Example: identifying the specific categorical etiologies for why “my car won’t start” requires
  - Knowledge of the possible causes
    - Dead battery,
    - Empty fuel tank,
    - Fuel pump failure,
    - Etc.
  - And knowledge of the features associated with the failure of each potential etiology
    - Dead battery/Voltage meter reveals battery produces no current
    - Empty fuel tank/Fuel gage reads empty
    - Fuel pump failure/Battery voltage adequate, fuel gauge reveals presence of gas, motor turns over but won’t sustain piston firing
Background

- Differential diagnosis is a categorization task primarily involving ill-defined disease categories,
- Evidence suggests that diagnostic error may be the third leading cause of death in the US,
- Given the primacy of knowledge in the performance of categorization tasks involving ill-defined categories...
  - There is a need for medical educators to better understand the knowledge base structures that cause System 1 and System 2 to perform both optimally and sub-optimally.
Exploring the knowledge base structures …

- **Differential Diagnosis (DDX) oriented, System 1 knowledge structures**
  - Disease Exemplars: Individually stored (episodic memory) portrayals of the features associated with each previously experienced example of a given disease.
  - Disease Prototypes: Abstracted portrayal (semantic memory) of a given disease; comprised of the features that both characterize the disease, and distinguish the disease from other disease competitors.

- **Differential Diagnosis (DDX) oriented, System 2 knowledge structures**
  - Disease/feature conditional probability estimates of the characteristic and distinguishing signs and symptoms associated with diseases.
  - Biomedical models describing …
    - How one or more tissues, organs or organ systems work together to support a given function (e.g., respiration, circulation, consciousness, etc)
    - The various pathological processes that can cause dysfunction of a given tissue, organ or organ system
    - How a given pathological processes adversely affects a given tissue, organ or organ system, and thereby gives rise to a cascade of pathophysiologic responses.
The following three illustrations demonstrate how System 1 knowledge structures (exemplars and prototypes) support System 1’s categorization-oriented information processing mechanisms.
System 1 based
Categorization via similarity/analogy ...
VIA EXEMPLARS

Experience with five different categories (A – E) is now stored in memory in the form of ONE exemplar for each category.

To which category (A – E) does instances 1, 2 and 3 belong?
Exploring the knowledge base structures...

- The deep, dark, mysterious ‘intellectual skill’ (similarity/pattern recognition mechanism(s)) enabling categorization via exemplars may simply be:
  - 1) ‘counting’ the number of features each exemplar shares with the instance at hand
    - Perhaps the simplest expression of ‘numeracy’
  - 2) selecting the disease handle attached to the exemplar that has the greatest number of instance-derived features.

- However, the ability to perform System 1 categorization via exemplars requires that the learner ‘experience’ at least one case exemplar for each of the common/important diseases likely to cause the problem at hand:
  - There is reason to believe that medical training programs provide a case example for only a fraction of all the diseases introduced during pre-clerkship training
  - Thus, ‘concept formation’ sufficient to support System 1 categorization via exemplars requires that training programs provide at least one case exemplar for each disease introduced during pre-clerkship training
System 1 based
Categorization via similarity/analogy ...
Via EXEMPLARS

Experience with three different categories (A, C & E) is now stored in memory in the form of FOUR different exemplars for each category.

To which category (A, C or E) does instance 1 belong?
Once again, the deep, dark, mysterious ‘intellectual skill’ (similarity/pattern recognition mechanism(s)) enabling categorization via exemplars may simply be:

1) ‘counting’ the number of features each exemplar shares with the instance at hand
   - Perhaps the simplest expression of ‘numeracy’
2) selecting the disease handle attached to the exemplar that has the greatest number of instance-derived features.

However, the ability to perform System 1 categorization when multiple exemplars are stored in memory, appears to represent a heavy ‘cognitive load’ – even given the assumption that System 1 performs its work ‘reflexively/unconsciously.

Should educators ‘leave it up to this alleged System 1 construct (multiple exemplars per disease category)’ to support reliably accurate diagnoses throughout the clinicians career?
System 1 based
Categorization via
similarity/analogy ...
VIA PROTOTYPES

Experience with three
different categories (A, C & E)
is now stored in memory in
the form of a frequency
based PROTOTYPE for each
category

To which category (A, C & E)
does instance 1 belong
Once again, the deep, dark, mysterious ‘intellectual skill’ (similarity/pattern recognition mechanism(s)) enabling categorization via exemplars may simply involve ‘counting’

1) But when using disease prototypes, the counting might involve the addition of the fractional weights associated with each of the competing disease prototypes

   A slightly more advanced expression of ‘numeracy’

2) selecting the disease handle attached to the prototype that has the greatest total weight.

However, the ability to perform System 1 categorization via prototypes requires that the learner ‘experience’ a number of case exemplars sufficient to form a robust prototype for each of the common/important diseases likely to cause the problem at hand

   There is little reason to believe that medical training programs consciously do this
Evidence suggests that categorization tasks are more heavily dependent upon knowledge rather than information processing/reasoning mechanisms.

System 1 information processing/reasoning mechanisms (as related to DDX) should no longer be assumed to be a deep, dark, mysterious intellectual skill. Rather, these mechanisms may be little more than an expression of numeracy.

- Addition of whole numbers for exemplar based categorization
- Addition of fractions for prototype based categorization

The primary impediment to the development of highly accurate System 1 based categorization capabilities appears to largely reside in ‘concept formation’.

- Exposure to the number and variety of case instances sufficient to produce a robust knowledge base of disease exemplars
- Guidance in how to translate disease-specific case exemplars into robust disease prototypes comprised of ‘high yield features’ (features which both characterize the disease at hand, and distinguish it from its competitors)