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

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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 wont 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 …

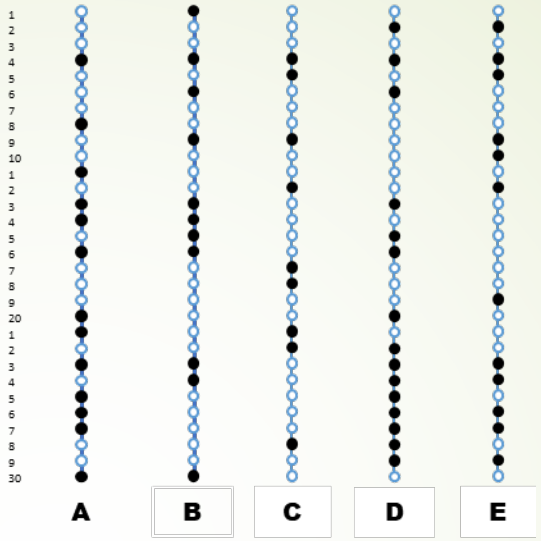
- Differential Diagnosis (DDX) oriented, System 1 knowledge structures
  - Disease Exemplars: Individually stored (episodic memory) portrayals of the features associated with each previously experienced example of a given disease.
  - Disease Prototypes: Abstracted portrayal (semantic memory) of a given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

Exploring the knowledge base structures …

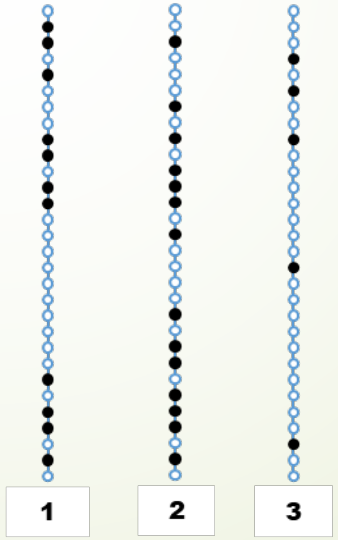
- The following three illustrations demonstrate how System 1 knowledge structures (exemplars and prototypes) support System 1's categorization-oriented information processing mechanisms

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?

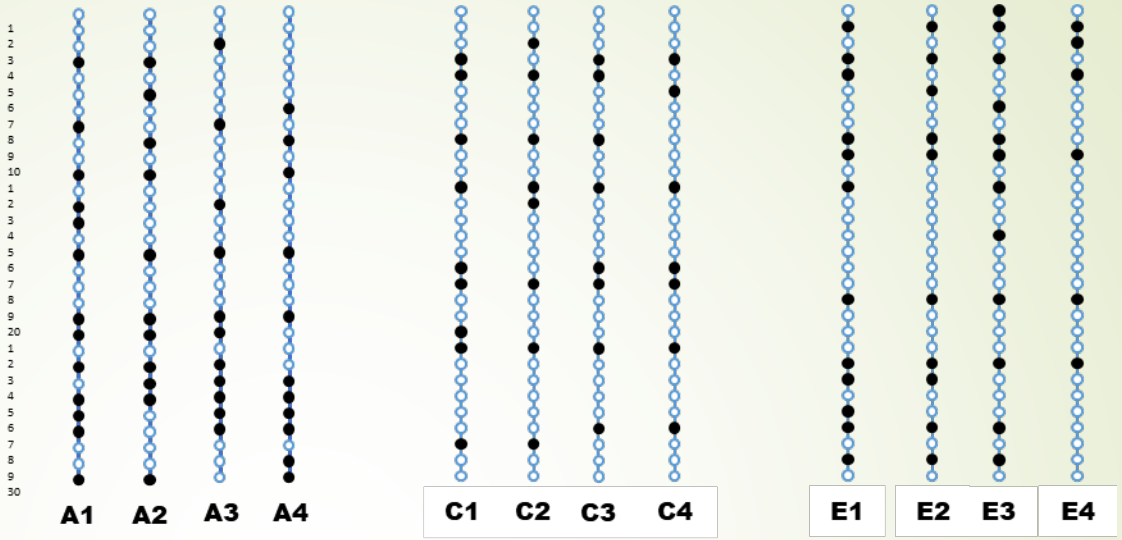


Exploring the knowledge base structures …

- 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



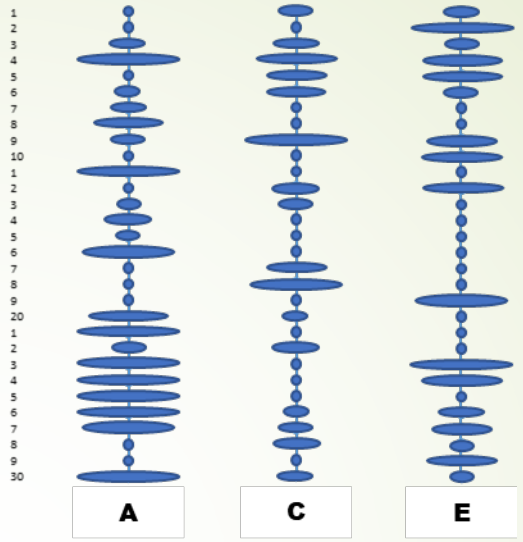
To which category (A, C or E) does instance 1 belong?

Exploring the knowledge base structures …

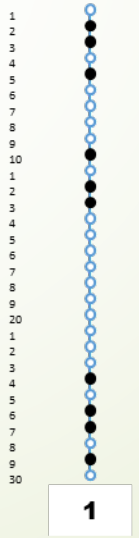
- Once again, the deep, dark, mysterious ‘intellectual skill’ (similarity/pattern recognition mechanism(s)) enabling categorization via exemplars may simply be:
  - 1) ‘counting’ the number of features each exemplar shares with the instance at hand
    - Perhaps the simplest expression of ‘numeracy’
  - 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 PROTOTOYPES

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



Exploring the knowledge base structures …

- 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

Exploring the knowledge base structures …

- 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)