

Is Experts' Knowledge Modular?

Herb Simon's Models of Expertise

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Understanding Behaviour: Two key questions

- **Bounded rationality**
 - Due to cognitive limitations (both in knowledge and computational capacity), humans have to 'satisfice'—find good-enough solutions
- **Role of environment**
 - The apparent complexity of an organism is largely a reflection of the complexity of the environment
- **These two questions recur in most of Simon's research, across a variety of scientific fields**
- **Expert behaviour offers an excellent domain for tackling both questions**

Overview of Talk

- **Simon's empirical work on expertise**
- **Simon's theoretical work on expertise**
 - Problem solving and selective search
 - Perception and memory
 - Chunking mechanisms in chess (EPAM model)
- **Simon's style of research**

Simon's Empirical Work on Expertise

- **A variety of domains**
 - Chess
 - Physics
 - Economics
 - Scientific discovery
- **A variety of techniques**
 - Verbal protocols
 - Naturalistic data
 - Experiments
 - » Novice / Expert comparisons
 - » Detailed studies of a single subject

Expertise: Key Phenomena (I)

- **It takes 10 years of intensive study and practice to become a world expert (Chase & Simon, 1973)**
- **Search is highly selective (De Groot, 1946; Newell & Simon, 1972)**
 - Minimal skill differences in type of heuristics used, depth of search, or number of states searched
- **Directionality of search (Simon & Simon, 1978)**
 - Experts search forward, from the givens
 - Novices search backward, from the goal
- **Pattern recognition guides selective search**

Expertise: Key Phenomena (II)

- **Perception and memory underpin skilled behaviour**
 - Clear skill differences with memory for briefly-presented chess positions (De Groot, 1946; Chase & Simon, 1973)
- **Identification of 'chunks' (units of perception and meaning) in a recall task (Chase & Simon, 1973)**
 - Absolute times (~2 seconds) may be used to identify chunks
 - High correlation between chunks defined by latencies and chunks defined by patterns of relations
- **Role of representations in problem solving and expertise**

Simon's Models of Expertise: Successful Simulations

- **A variety of computational models in a number of domains**
 - Mnemonics (digit-span task)
 - Chess
 - Physics
 - Economics
- **Most of them use production systems (Newell & Simon, 1972) or chunking mechanisms (Feigenbaum & Simon, 1962, 1984)**

Models of Heuristic Search

- **Models of chess problem solving (Newell, Shaw & Simon, 1958; Baylor & Simon, 1966)**
- **How can human beings, in spite of their bounded rationality, become experts in combinatorial tasks?**
- **Formalised several key ideas related to bounded rationality:**
 - presence of goals
 - the dynamic adjustment of expectation
 - heuristic search
 - satisficing

Experts' Perception and Memory

- **Expertise is due to a highly efficient mode of perception**
- **Chunking theory (Chase & Simon, 1973)**
- **~ 100,000 chunks needed for expertise**
- **Chunks are linked to possible moves (recognition and association mechanism)**
- **PERCEIVER, MAPP, CHREST**
- **Question of selective search still at the centre of interest**

EPAM

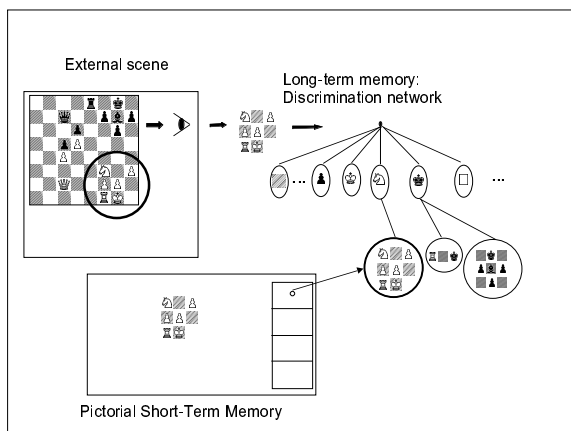
Elementary Perceiver and Memoriser

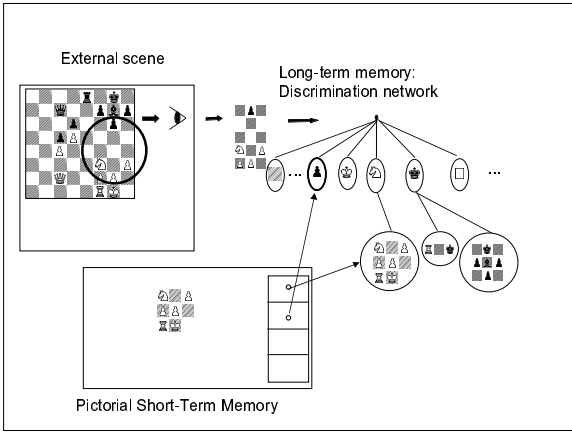
- First applied to verbal learning (Feigenbaum & Simon, 1962, 1984)
- Long-term memory is indexed as a discrimination net, which grows as a function of learning
- Self-organising system
- One of the first learning programs around
- Short-term memory is limited to 3-7 chunks
- Time parameters are used

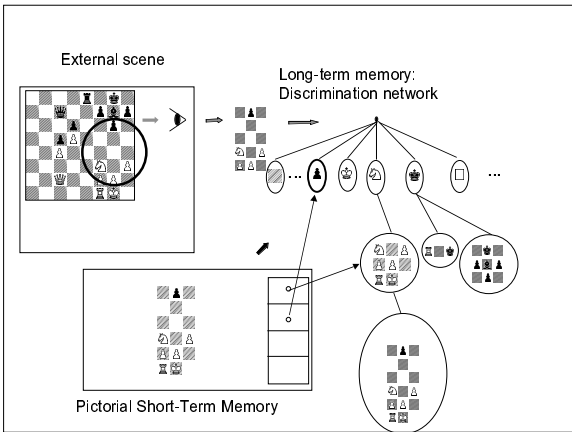
CHREST

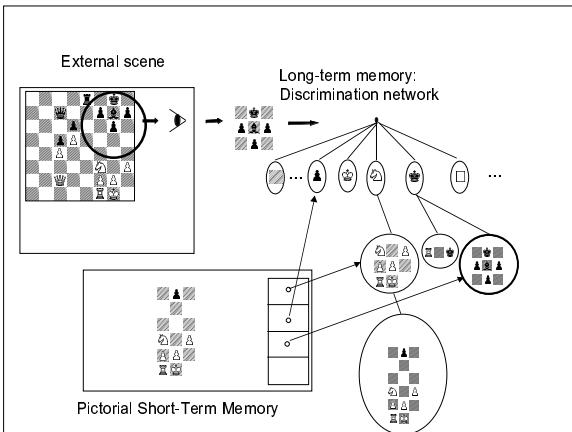
Chunk Hierarchy & RETrieval STructures

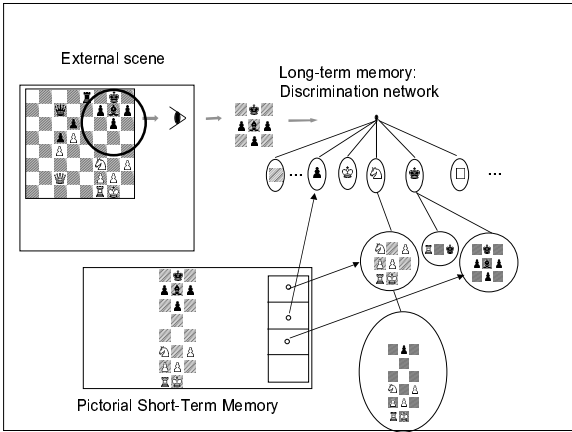
- Gobet & Simon (1996, 2000)
- Modification of the chunking theory
- Combines low- and high-level aspects of cognition
- Frequent chunks evolve into schemas (templates)
- Templates have slots for pieces and squares allowing values to be encoded rapidly
- Offers a mechanism implementing retrieval structures

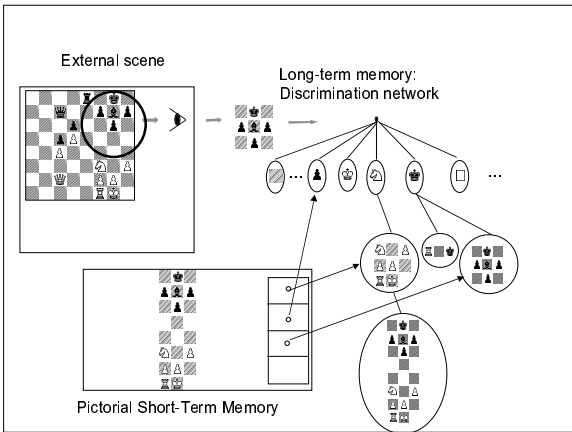












Phenomena Simulated

- **Eye-movement simulations**
- **Memory simulations**
 - Type of errors
 - Recall of modified positions (e.g., random positions)
 - Role of presentation time
- **Identification of chunks**
 - Correspondence between latencies and patterns of relations
- **Problem solving**
 - CHUMP plays chess by pure pattern recognition

➔ **EPAM and CHREST learning mechanisms capture structure of the environment**

Other Applications of EPAM Mechanisms

- **Concept formation**
- **Explanation of individual differences**
- **Implicit cognition**
 - Intuition, insight
 - Tip-of-the-tongue phenomenon
- **Consciousness**
- **Education**
 - Currently, not much emphasis on condition parts of productions in teaching
 - Design of a curriculum for high-school mathematics in China

Simon's Scientific Style (I)

- **Application of two main questions (bounded rationality and role of the environment) to a number of domains**
- **Interdisciplinarity**
- **High reliance on, and excellent knowledge of, (sometimes obscure) previous work**
 - Role of Otto Seiz (1922) in the development of production systems
 - Role of De Groot (1946) in the development of the chunking theory
 - Role of behaviourism (through Eleanor Gibson) in the development of EPAM

Simon's Scientific Style (II)

- **Penchant for detailed data and detailed analyses, using a variety of sources (eye movements, verbal protocols, errors, etc.)**
- **Search for the constants of mind (e.g., 8 seconds to create a chunk)**
- **Liking for simple experimental designs, with few subjects**
- **Dislike for complex statistical techniques**
 - No test necessary if the effect is strong enough
- **Dislike for vague theories**

Simon's Scientific Style (III)

- **Emphasis on simple mechanisms in modelling**
- **Economy in theorising: same mechanisms used in different domains**
- **Theories emphasise cognitive limits**
 - Capacity of visual short-term memory (4 items)
 - Time to learn a chunk (8 seconds)
 - Seriality of high-level cognition
- **Branching trees as modelling tools**
 - Discrimination tree of EPAM
 - Models of heuristic search

Life as Heuristic Search

"In describing my life, I have situated it in a labyrinth of paths that branch, in a castle of innumerable rooms a heuristic search for the solution of an ill-structured problem."

Herbert A. Simon
Models of My Life (1991)
