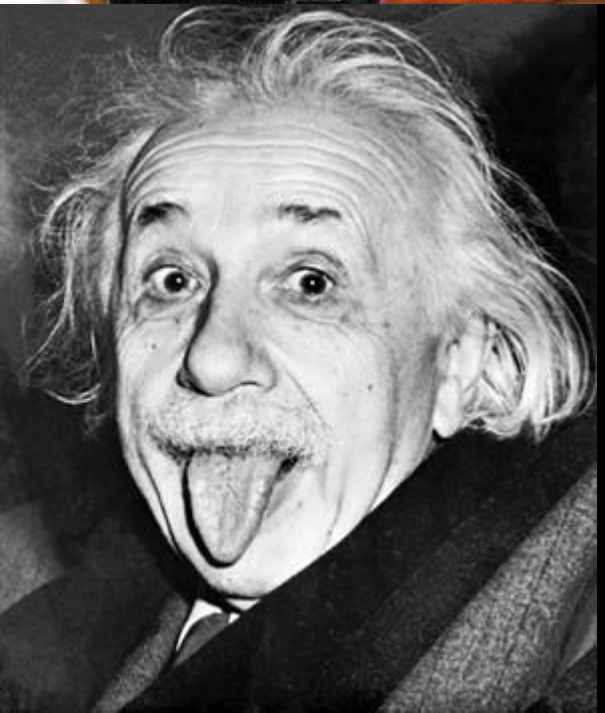
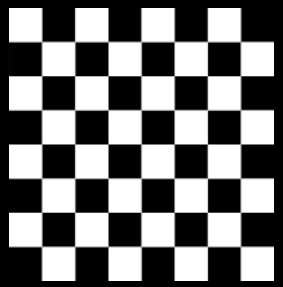


Expertise

Paula Parpart

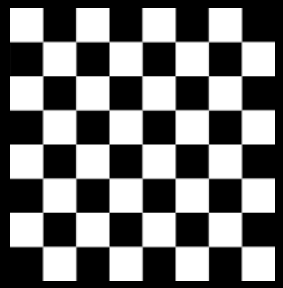
16th January 2017

In early 80s, two Hungarian eduators, Laszlo and Klara Polgar decided to challenge the popular assumption that women don’t succeed in areas requiring spatial thinking, such as chess…



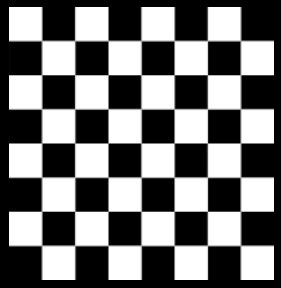
They wanted to make a point about the power of education.

They homeschooled their 3 daughters and started playing chess with them at a very young age.



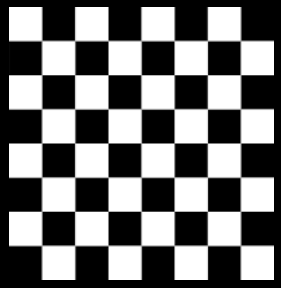
Fast forward: By 2000, all three daughters had been ranked in the top ten female players in the world.

The youngest, Judith, had become a grand master at age 15, breaking previous record. Today she is one of the world's top players and has defeated almost all the best male players.



What did they do?

Systematic training and daily practice.



Discussion Intermezzo

To what extent is superior performance innate or reproducible (with practice)?

- Since the 80s, assumptions about gender differences in expertise are not the only thing that crumbled.

  - Benjamin Bloom (1985): critical factors that contribute to talent – found no early indicators when taking retrospective look at 120 childhoods of virtuosos

  - Research showed no correlation between IQ and expert performance in chess, music, sports, medicine..

So what *does* correlate with success?

- Bloom's work: all superb performers had practiced intensively, had studied with devoted teachers, had been supported enthusiastically by their families throughout developing years.

- Consistently and overwhelmingly, evidence showed that experts are made, not born.

- Cambridge Handbook of Expertise and Expert Performance (Ericsson et al., 2006)

What is expertise?

- Real expertise passes 3 tests (Erisson et al., 2007):
  1) Performance that is consistently superior to that of the expert's peers
  2) Produces concrete results (e.g., brain surgeons' success rates, sport competitions)
  3) True expertise can be replicated and measured in the lab

Can be difficult to measure!

How to measure expertise?

- For example: Take a representative situation and reproduce in the lab. For example, present emergency room nurses with scenario that simulate life-threatening situations.
- Compare the nurses' responses in the lab with actual outcomes in the real world
- Performance in simulations in medicine, chess, sports closely correlates with objective measures of expert performance

What is expertise?

It is not…

- Individual accounts: anecdotes, selective recall, one-off events → false memories and self-serving biases

- "Trusting your gut": Improving performance by relaxing and trusting your intuition

Informed intuition is the result of deliberate practice.

- Changing method: cannot make up for consistency and carefully controlled efforts.

What is expertise?

- *Expertise* refers to the characteristics, skills and knowledge that distinguish experts from novices (Ericsson, 2006)

- *Expert* - "one who has acquired special skill in or knowledge of a particular subject through professional training and practical experience”

- Eg medical doctors, accountants, computer programmers, scientists, … chess players, writers, artists, musicians, athletes…

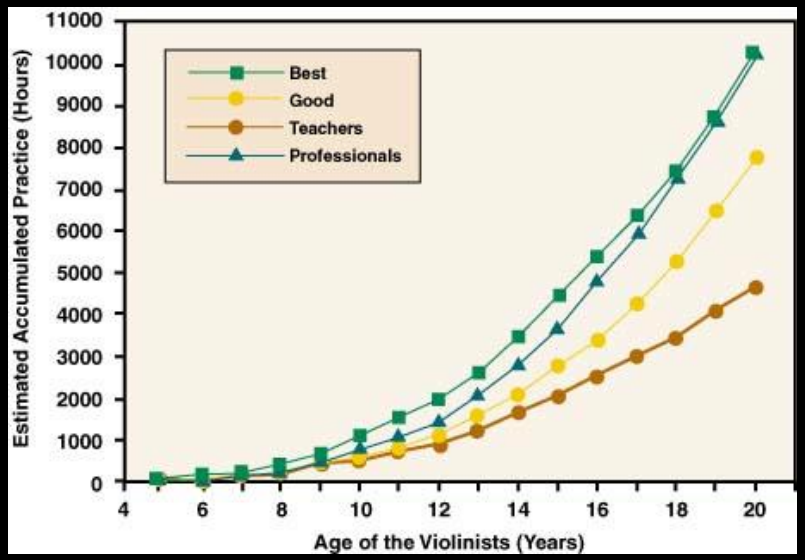
What makes an expert?

- Ericsson and Lehmann (1996)

1. Basic capacities (e.g., IQ) do not predict expertise in a domain
2. Superior performance often domain specific and transfer outside narrow area of expertise is limited
3. Systematic differences between experts and novices reflect attributes acquired by the experts during lengthy training
   - 10 years; 10,000 hours (eg 20hrs per week!)

Quality of practice

- Mere length of experience not sufficient for expertise (Ericsson & Lehmann, 1996)
- Deliberate practice--activities designed to improve specific aspects of performance
  - Eg expert musicians spent most time on solitary practice



Ericsson et al. (1993)

Expert performance framework

- Deliberate practice for at least 10 years
- Practice where you are *NOT* performing well yet
- Optimize learning (similar to information gain/uncertainty reduction framework)
- "During solitary practice the experts reported working with full concentration on improving specific aspects of their music performance—often identified by their master teacher at their weekly lessons" (Ericsson, 2007)

Expert performance framework

- Deliberate practice for at least 10 years
  - Practice where you are *NOT* performing well yet
  - Optimize learning

Giftedness view	Expert performance view
• Genetic differences in innate talent can explain expert performance	• No evidence for individual genetic differences in expertise exist, except for height and body size in sports (Ericsson, 2006)

Expert performance framework

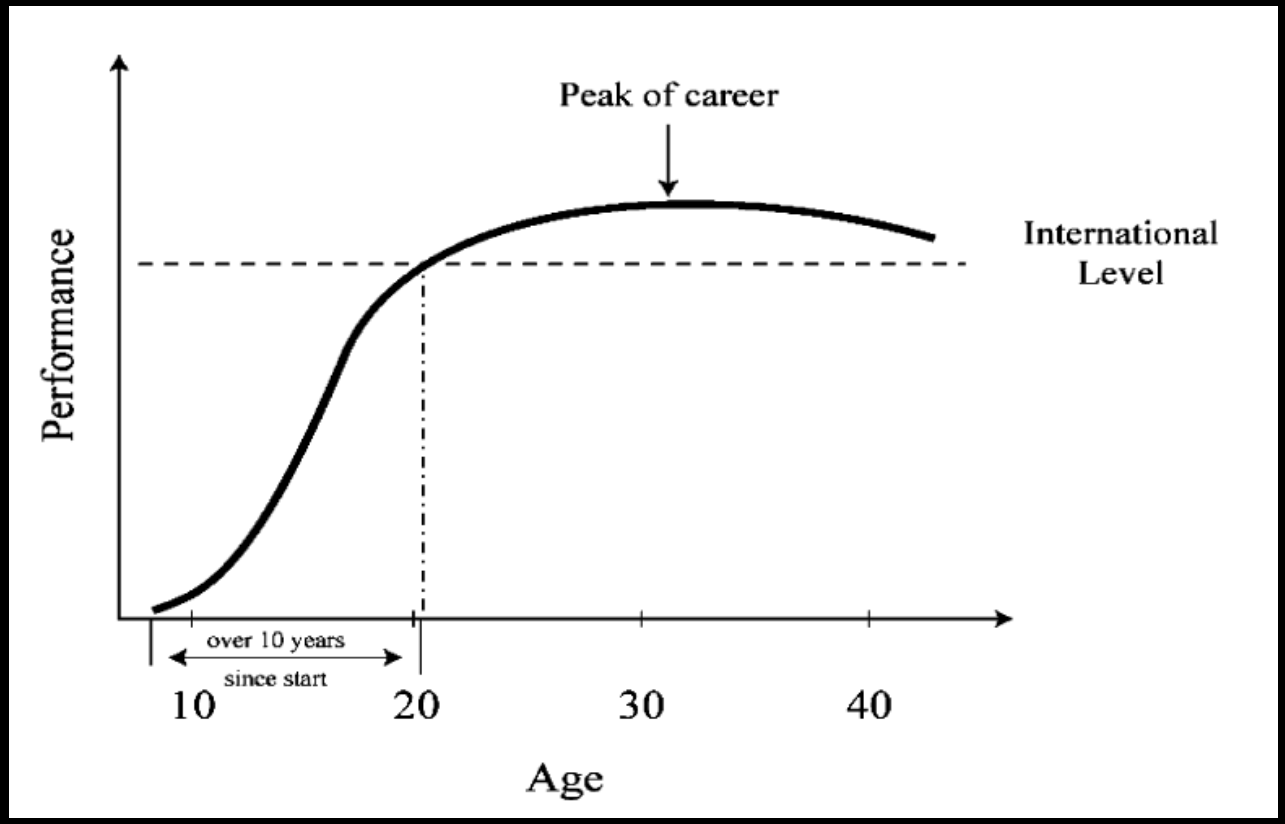
- Deliberate practice for at least 10 years
  - Practice where you are *NOT* performing well yet
  - Optimize learning

Giftedness view	Expert performance view
• "Innate talent *limits* attainable performance of healthy individuals" = fixed upped limits of performance based on genes	• Even individuals who might be most 'talented' need around 10 years of intense practice before they reach level of consistently excelling

Expert performance framework

- Deliberate practice for at least 10 years
  - Practice where you are *NOT* performing well yet
  - Optimize learning

Giftedness view	Expert performance view
• "Innate talent *limits* attainable performance of healthy individuals" = fixed upped limits of performance based on genes	• Idea that individuals enter a domain and rapidly reach high levels of performance with little effort is false (*genius*)



Ericsson et al., 2007

Giftedness view	Expert performance view
• Top performance can only be reached by people with “gifts”	• The age at which peak performance is reached is mid-to-late twenties for sports, and thirties and forties for arts and sciences

Expert performance framework

Giftedness view	Expert performance view
• "Genetic predispositions *limit* attainable performance of healthy individuals"	• Evidence for large improvements in the highest level of performance • Evolutionary changes involving the emergence of new genes that increase adaptation would take too long and could not explain dramatic increase in performance

Expert performance framework

- Any statistical problems with these past studies?
- Could there be a selection bias? (innate talent)
- Could parts of both theories be true?

Giftedness view	Expert performance view
• "Genetic predispositions *limit* attainable performance of healthy individuals"	• Evidence for large improvements in the highest level of performance

Experts

Experts

- The same cognitive constraints as everyone;
- Task-specific adaptations to maximise performance despite these constraints;

- Knowledge representation
  - encoded via key domain-related concepts and solution procedures
  - Enables reliance on long-term memory
  - Freeing up of working memory capacities

Quality of knowledge representation

- Superior quality of experts' mental representations allows them to adapt rapidly to changing circumstances and anticipate future events

- The same acquired representations are essential for experts' ability to monitor and evaluate their own performance (Ericsson, 1996). Experts…
  - ...better at judging difficulty of a physics problem than non-experts (Chi et al., 1982)
  - ...better at predicting how many times they would have to see a configuration of chess pieces in order to reproduce the board

Quality of knowledge representation

- Thus experts can keep improving their own performance by designing their own training and assimilating new knowledge (Ericsson, 2000)

- **Self-coaching: e.g., neurosurgeons learn from mistakes**

Domains

- Chess
- Physics
- Medical Diagnosis
- (Natural Decision Making) if we have time…

Chess expertise

- Early studies (De Groot, 1965)
  - Players given chess problem and think aloud as they decide next move

Variable	Grand masters (5)	Experts (5)
Time to choose move	9.6min	12.9min
No. of different first moves considered	4.2	3.4
Max depth of search (moves)	6.8	6.6
Total no. of moves considered	35.0	30.8
Rated value of move selected (max = 9)	8.2	5.2

  - Grand Masters make higher quality moves
  - No clear difference in extensive search or moves considered

Memory for chess positions

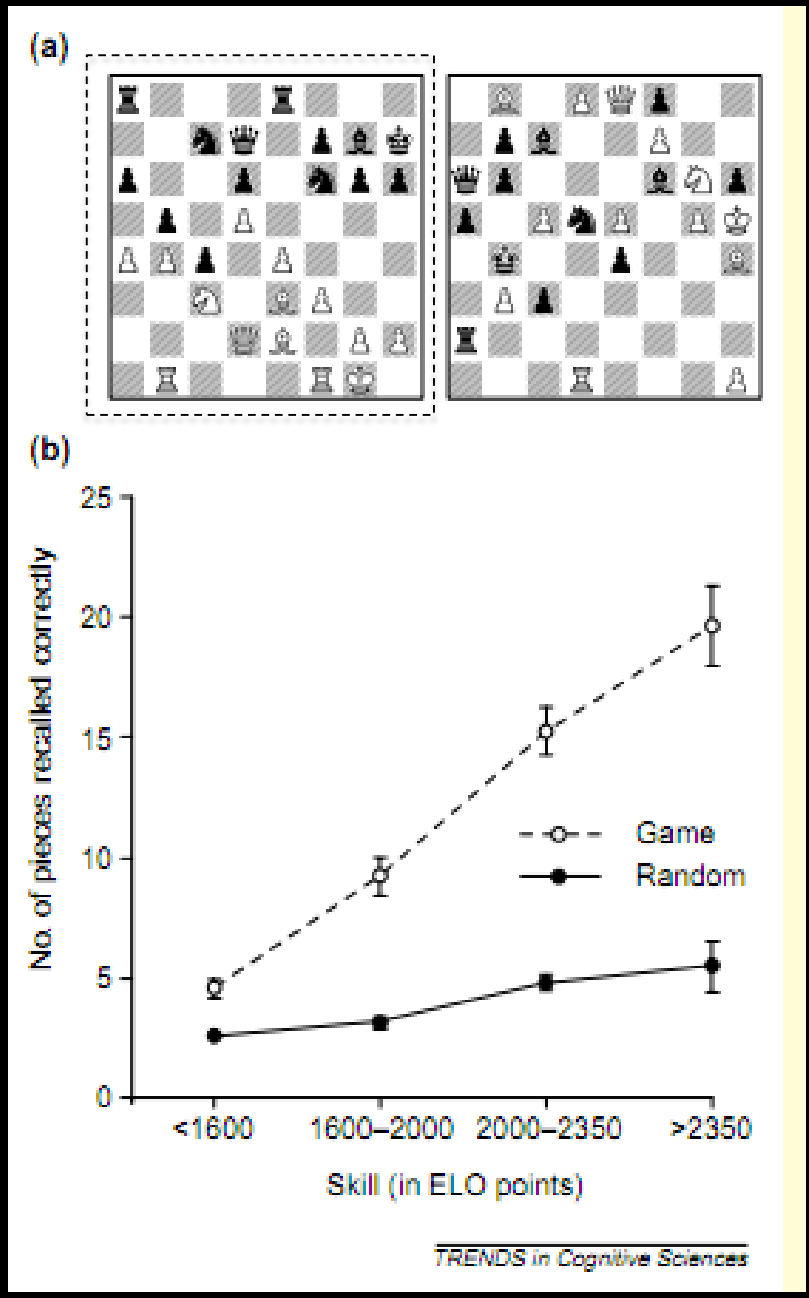
- As expertise in chess increases so does memory for chess positions

- https://www.youtube.com/watch?v=rWuJqCwfjjc

- Original studies suggested no differences between experts and novices for random set-ups

Memory for chess positions

- As expertise in chess increases so does memory for chess positions
- Original studies suggested no differences for random set-ups
- Meta-analysis suggests *slight* increase for random positions



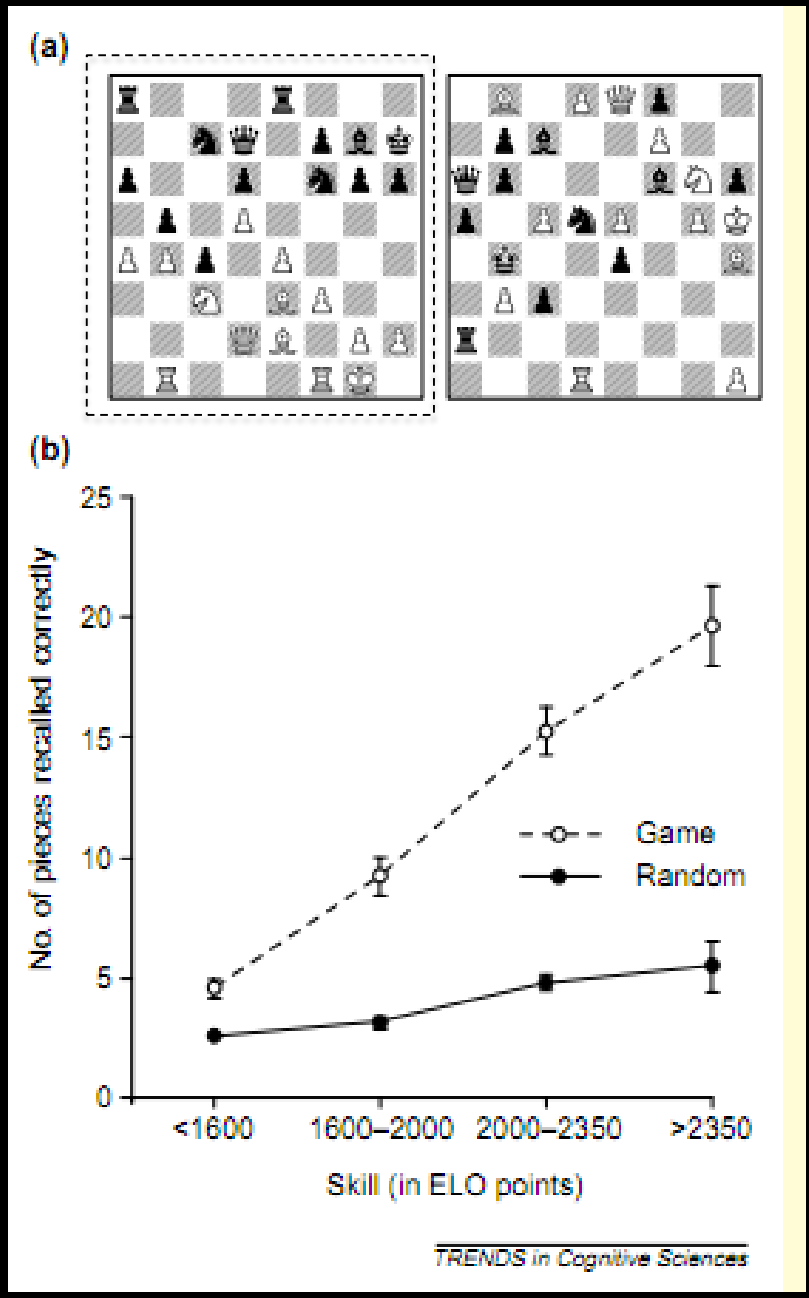
(after <= 10 secs exposure)

From Gobet et al. (2001) – avge of 13 studies

Memory for chess positions

- Meta-analysis suggests *slight* increase for random positions

- "The fact that perceptual chunking provides masters with an advantage even in random positions offers strong support for chunk-based theories" (Gobet et al, 2001)



(after <= 10 secs exposure)

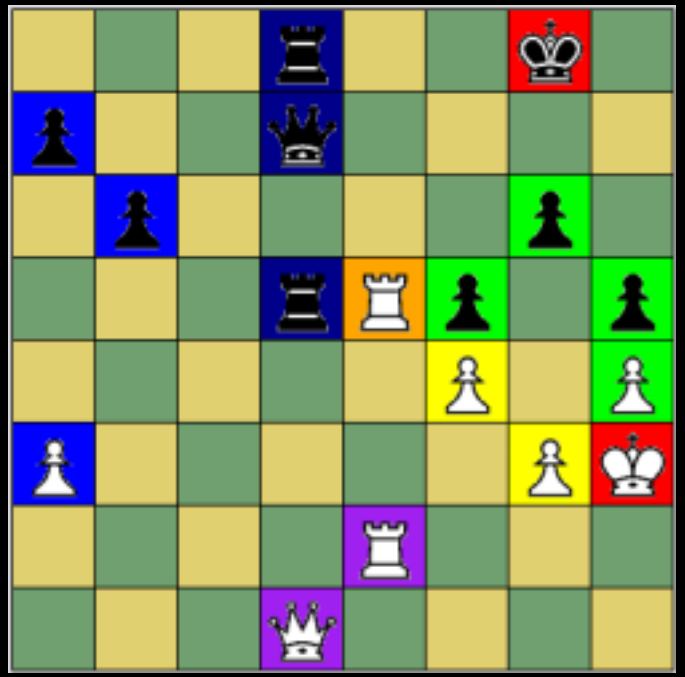
From Gobet et al. (2001) – avge of 13 studies

Chunks

- *Chunks* as building blocks of chess knowledge & skill

  Chase & Simon (1973)

- To account for differences between novices and experts in memory tasks, Chase and Simon added assumptions about capacity of short-term memory (STM) which is limited to 7 items: **Chess position = chunks**



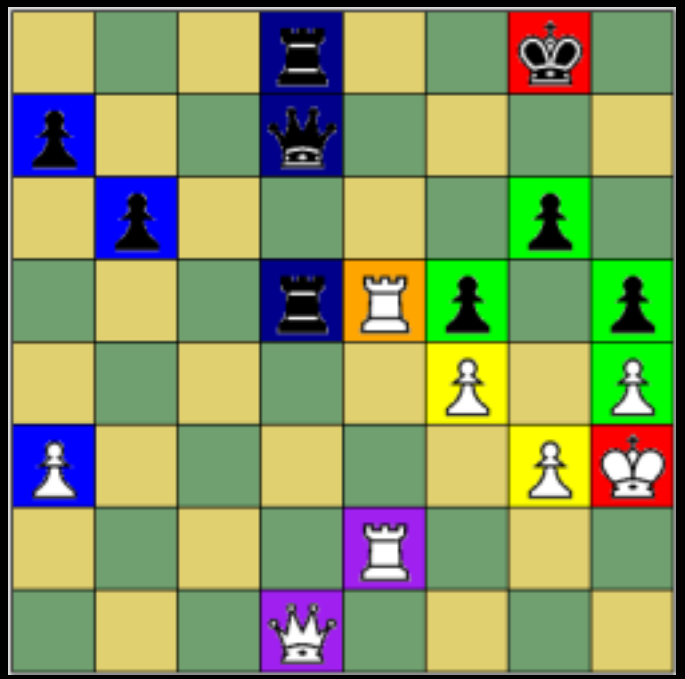
Chunks

- *Chunks* as building blocks of chess knowledge & skill

  Chase & Simon (1973)

- Chunks = groups of pieces forming perceptual and semantic units

- Recall consists in unpacking the information contained in chunks



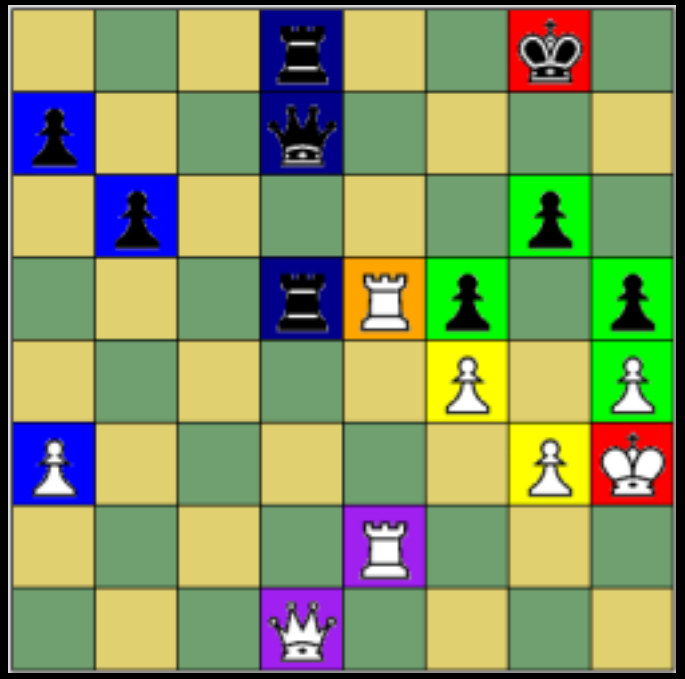
Chunks

- *Chunks* as building blocks of chess knowledge & skill

  Chase & Simon (1973)

- Chunks = groups of pieces forming perceptual and semantic units

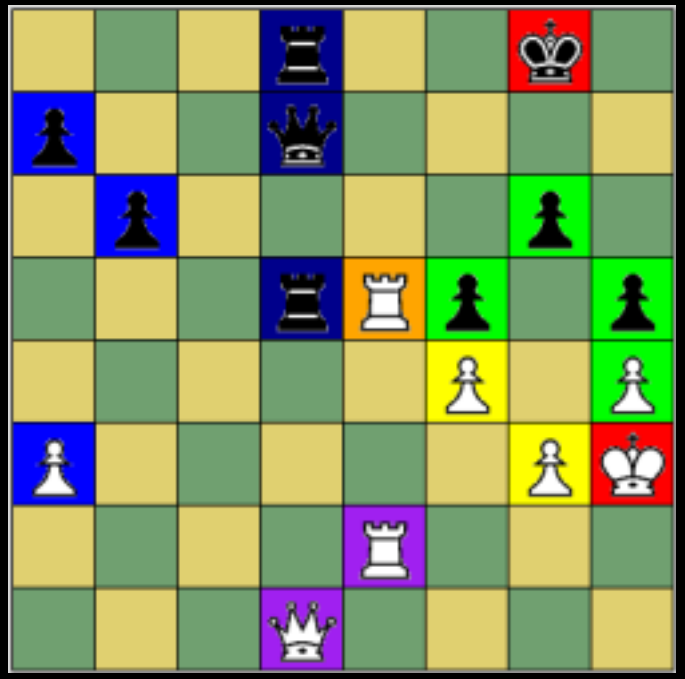
- Chess Masters can remember chess positions better, because they have acquired **more and larger** chunks than weaker players



Chunks

Chase & Simon (1973)

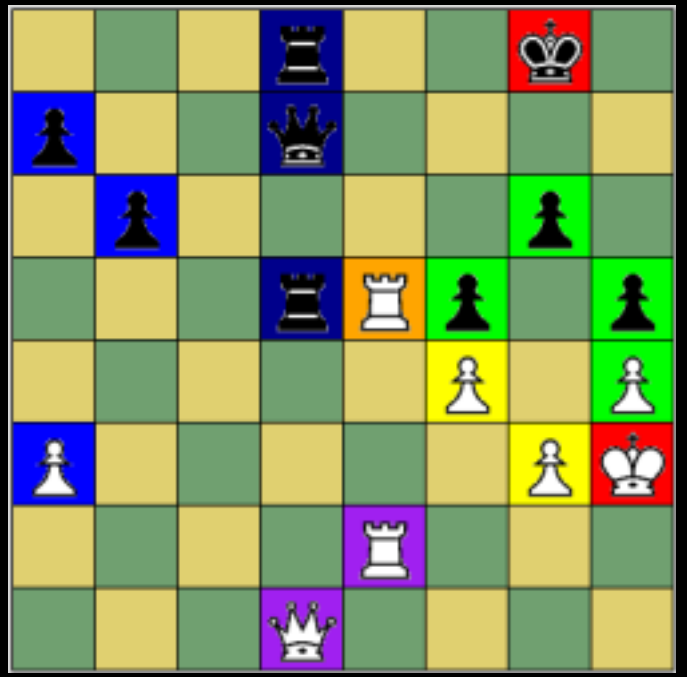
- Chunks provide information about what move to play, what plan to follow, and partial evaluation
- To account for masters ability to find good moves
- Perceptual chunks act as conditions to actions



Chunks

Chase & Simon (1973)

- Recognition mechanisms of chunks occurs both in the external board, but also internally in the imagined positions



- → chunking theory explains both masters' ability to find moves 'intuitively', i.e., almost instantly, and ability to carry out selective search when necessary

Chunks

Chase & Simon (1973)

- Chunking theory mechanisms were able to explain phenomena outside of chess as well: expertise in arts, sports, sciences (Richman et al., 1996)

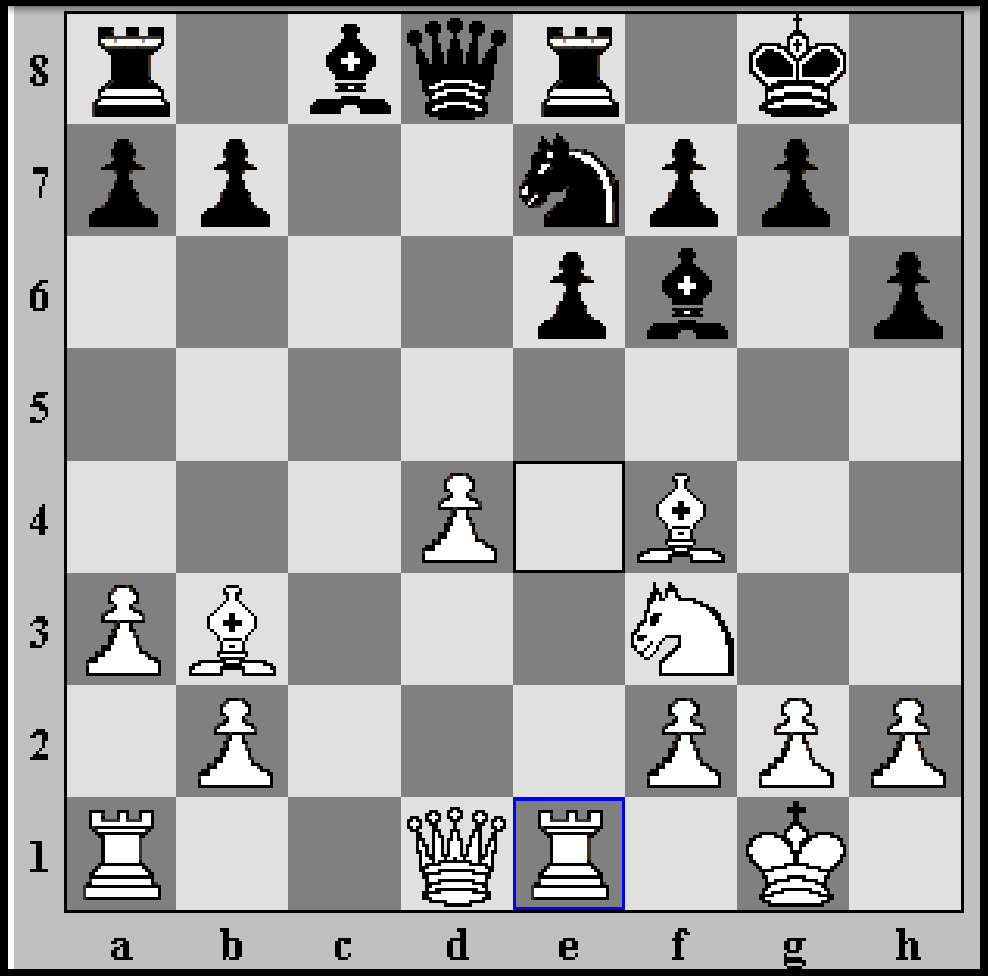
Chunks

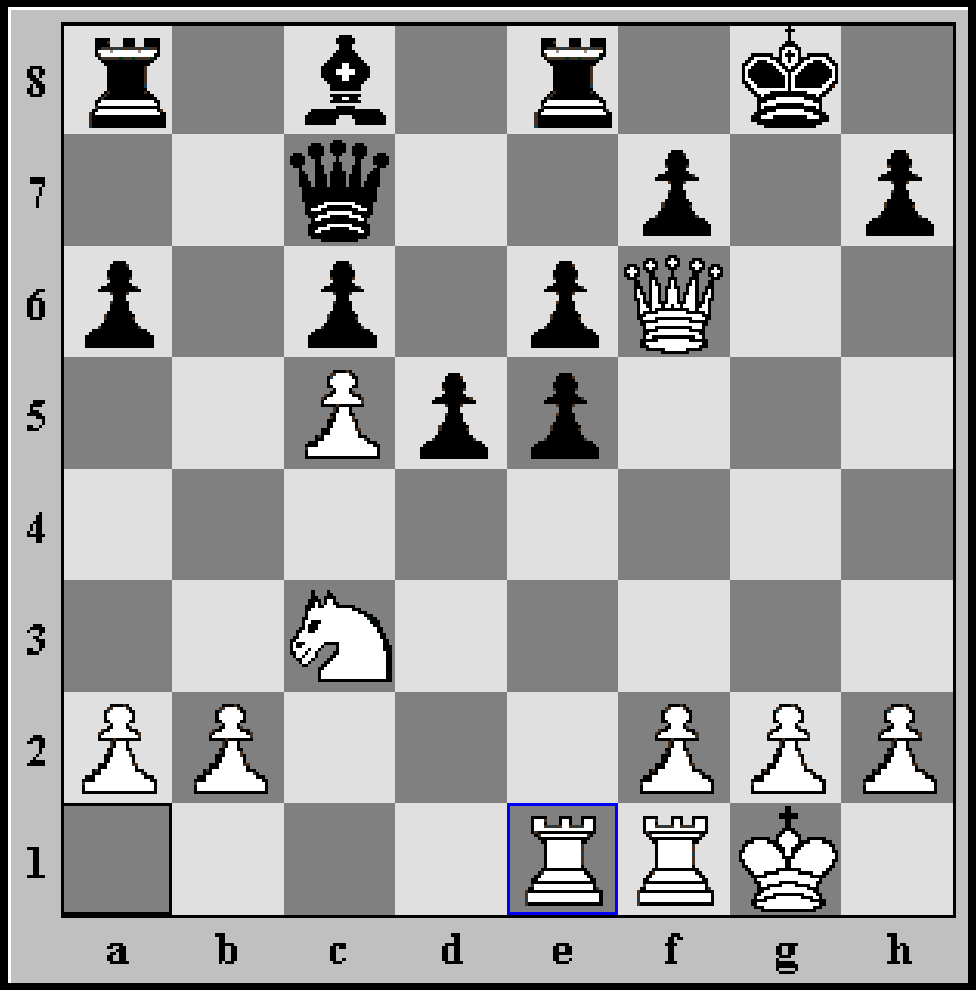
- Experts have more chunks stored in LTM
  - ~50,000 chunks necessary to become an expert (computer simulation with MAPP)
- Identify key features of a position
  - Better quality search
  - Better memory for chess positions
  - (and slight advantage for random set-ups due to a few meaningful chunks)
- *Moves* also stored as chunks
  - Board positions thus generate a sequence of stereotypic moves

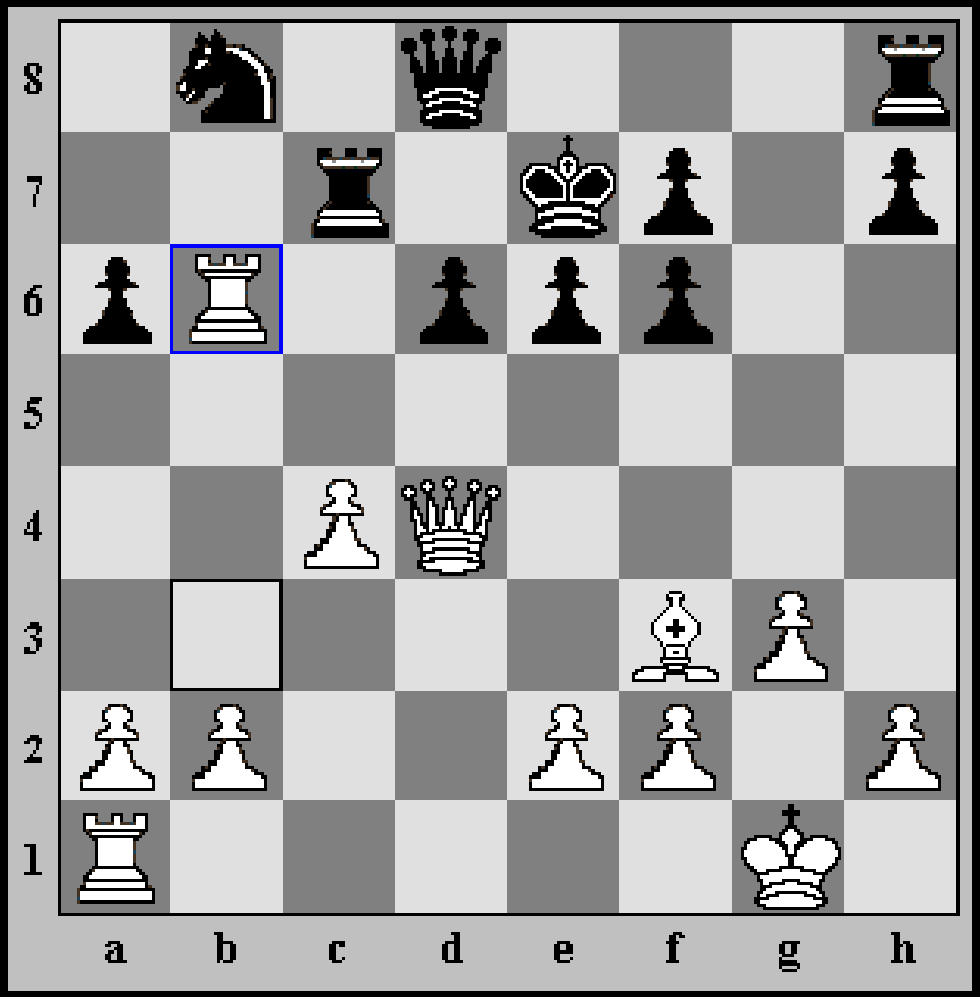
Beyond chunks

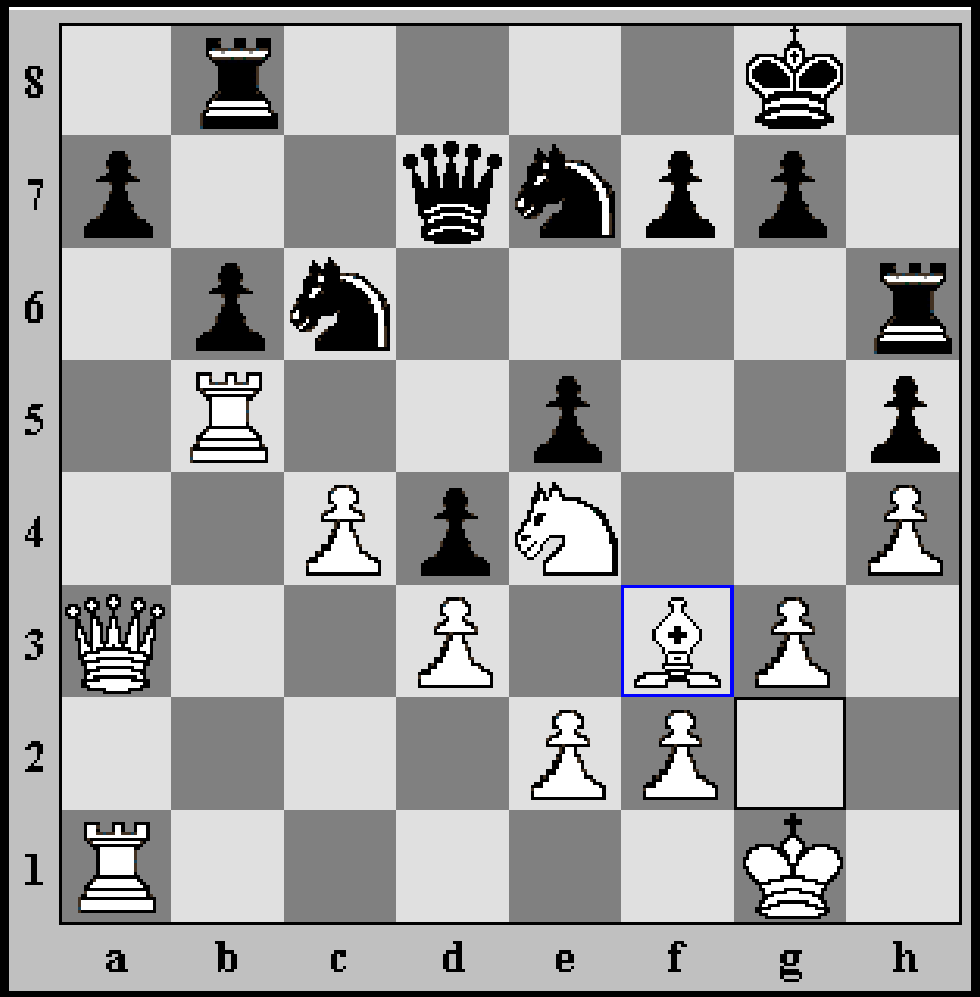
Gobet & Simon (1996)

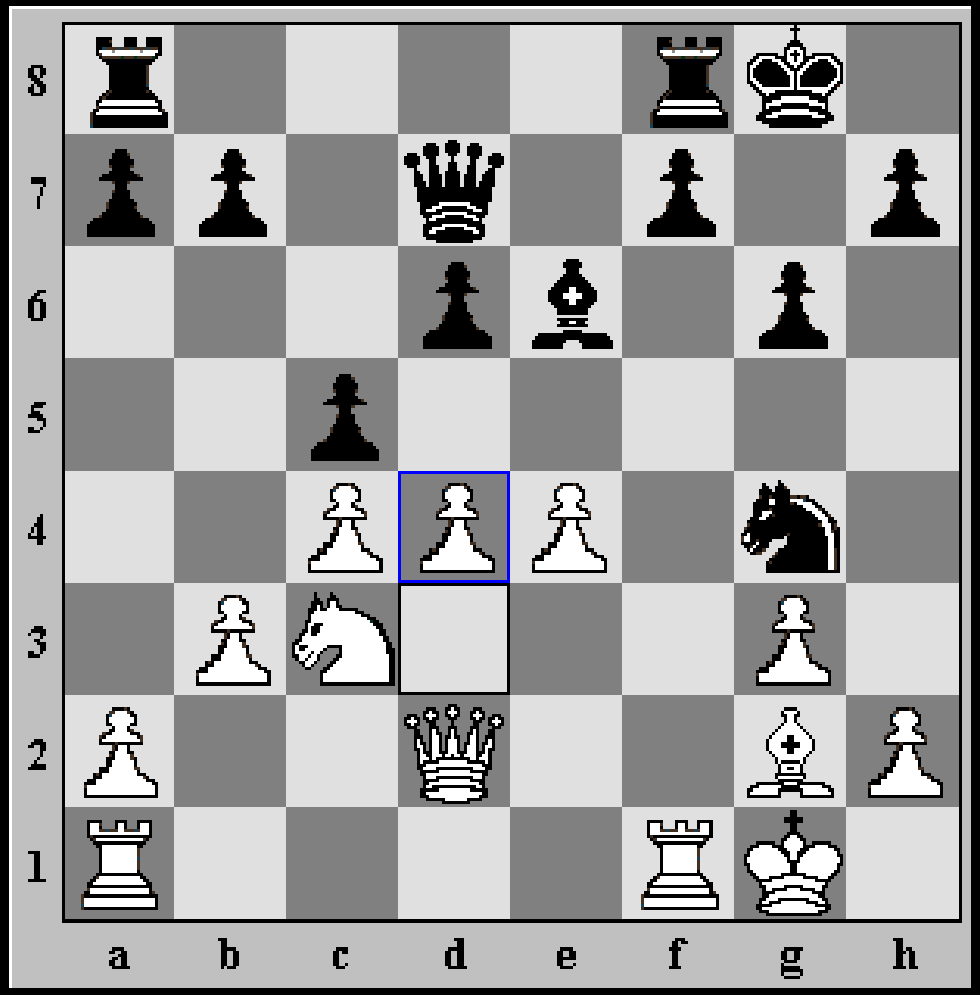
CLICK TO START THE EXPERIMENT

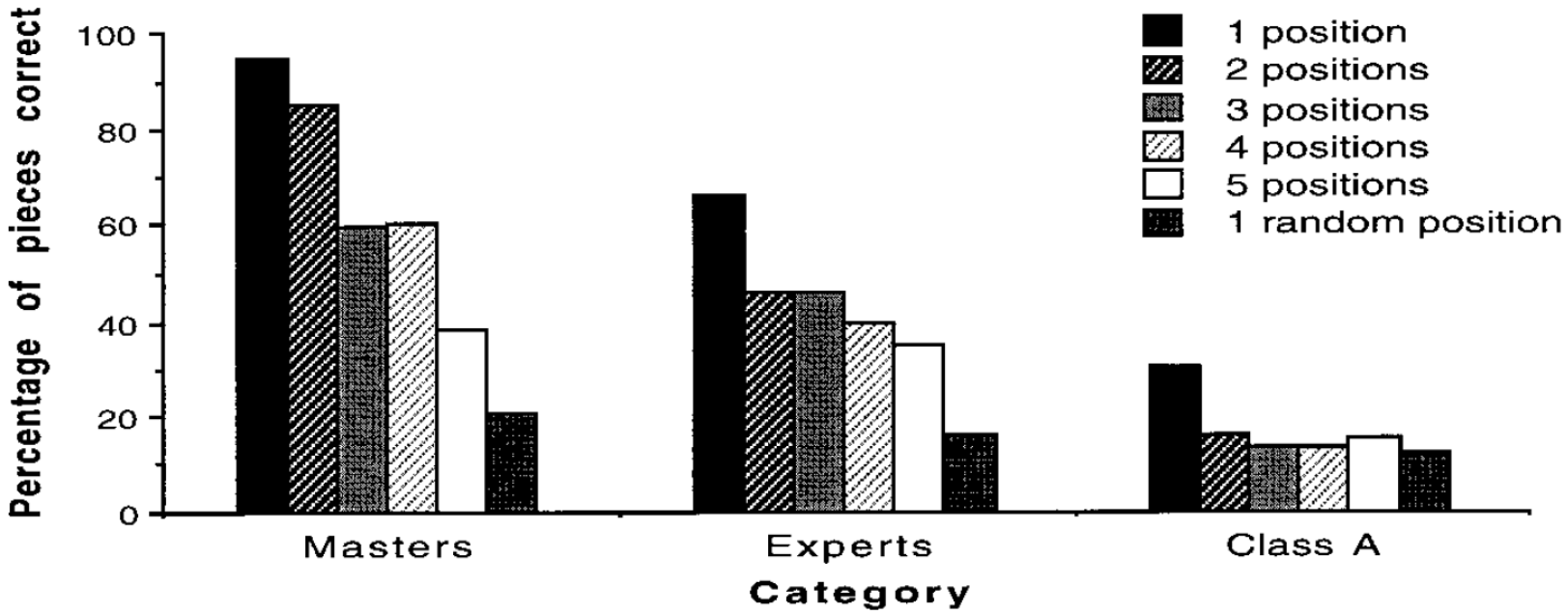

8
7
6
5
4
3
2
1
a b c d e f g h


8
7
6
5
4
3
2
1
a b c d e f g h


8
7
6
5
4
3
2
1
a b c d e f g h


8
7
6
5
4
3
2
1
a b c d e f g h


8
7
6
5
4
3
2
1
a b c d e f g h


Percentage of pieces correct
100
80
60
40
20
0
1 position
2 positions
3 positions
4 positions
5 positions
1 random position
Masters
Experts
Class A
Category

Templates

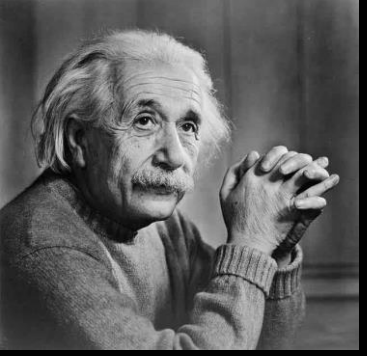
- *Templates* not just chunks (Gobet & Simon, 1996)
  - Larger structures than chunks
  - High level schematic structures that evolve from perceptual chunks
  - Explains how players access information via pattern recognition
- *Template theory* implemented by a computational model and applied to memory in other domains (Gobet et al., 2001)

1 International Master (Gobet) learned to recall 70% of pieces from 9 boards!

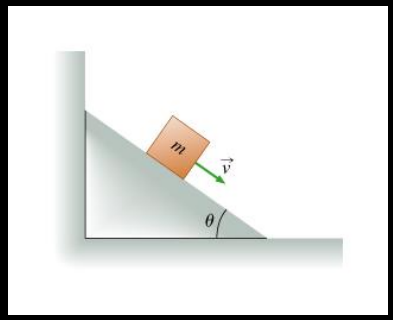
Chess expertise

- Human chess players are selective in their search
  - Expert players selection is better!

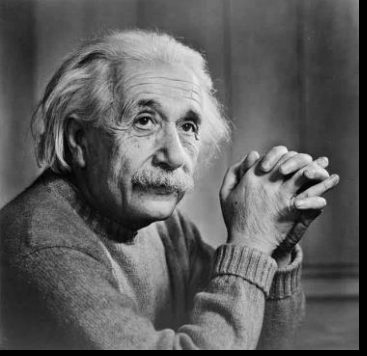
- The search of the skilled player is guided by heuristics that permit it to be restricted to a small tree of possibilities. The heuristics, in turn, rest upon recognition of familiar patterns or chunks.



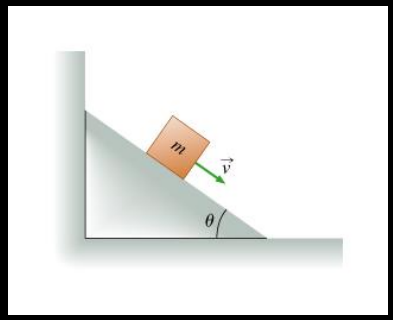
Physics problems



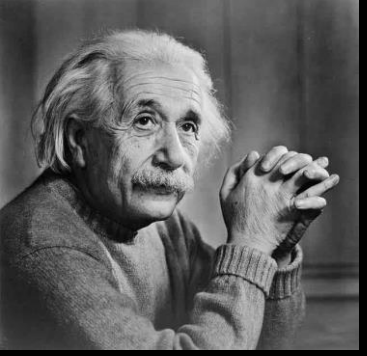
- Expert vs. novice differences
  - Physical intuition
  - Forward vs. backwards reasoning
  - Deeper knowledge structures



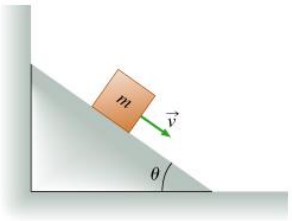
Physical intuition



- Experts apply physical intuition prior to using equations (Larkin, 1980; Simon & Simon, 1978)
  - Construction of a 'physical' representation/model
  - Refers to real-world mechanisms
- Provides basis for generating relevant equations
- Checking possible errors
- Global description of problem
- Permits inferences
  - (Beyond explicit information in the problem [e.g., coefficient of friction related to angle])



Strategies



- Novices use *backwards*-working
- Experts use *forwards*-working

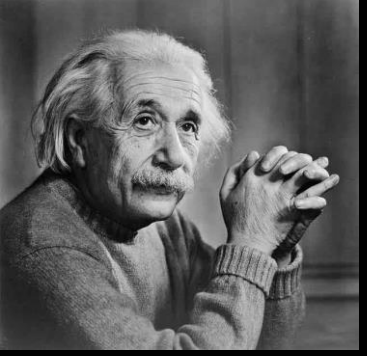
E = f(A,B)	eq1
D = f(C,E)	eq2

Suppose A,B,C given. Need to solve for D

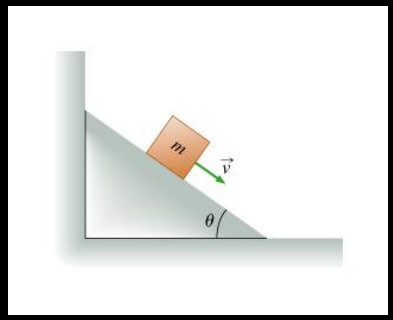
Backwards – use eq2 first because it contains required answer D; E is unknown so use eq1 to compute it; then return to eq2 to compute D

Forwards – use eq1 to compute E from A & B; use eq2 to compute D

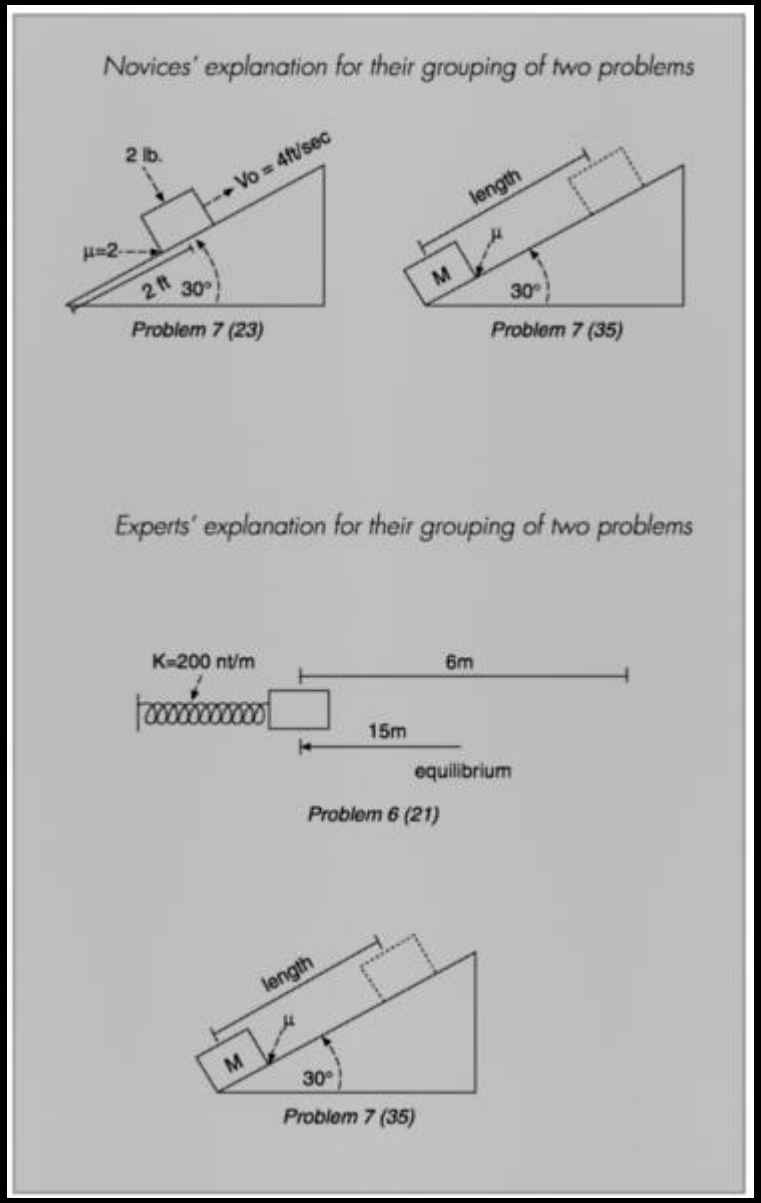
- Experts work from the variables given in the problem, successively generating the equations that can be solved from the given information;



Knowledge structures



- How do experts select correct principles?
- Experts develop repertoire of familiar problem categories
- Chi et al (1982) study–
  - Advanced PhD and UG students sort physics problems on basis of similarities in how they would solve them
  - No differences in number of categories or time taken
  - But novices sorted by *surface structure* – problems similar in terms of objects & key words
  - Experts sorted by *deep structure* – in terms of principles involved in solution (e.g., conservation of energy)



Explanations

Novice 1: These deal with blocks on on incline plane.

Novice 5: Incline plane problems, coefficient of friction.

Novice 6: Blocks on inclined planes with angles.

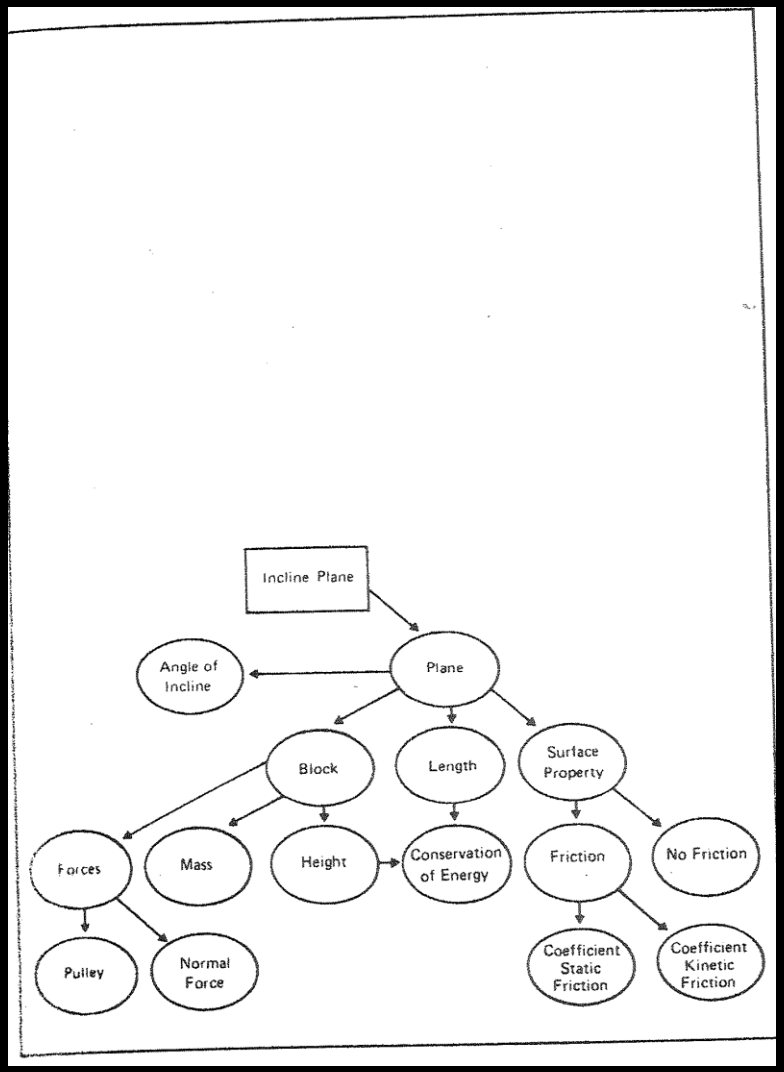
Expert 2: Conservation of energy.

Expert 3: Work-theory theorem. They are all straight-forward problems.

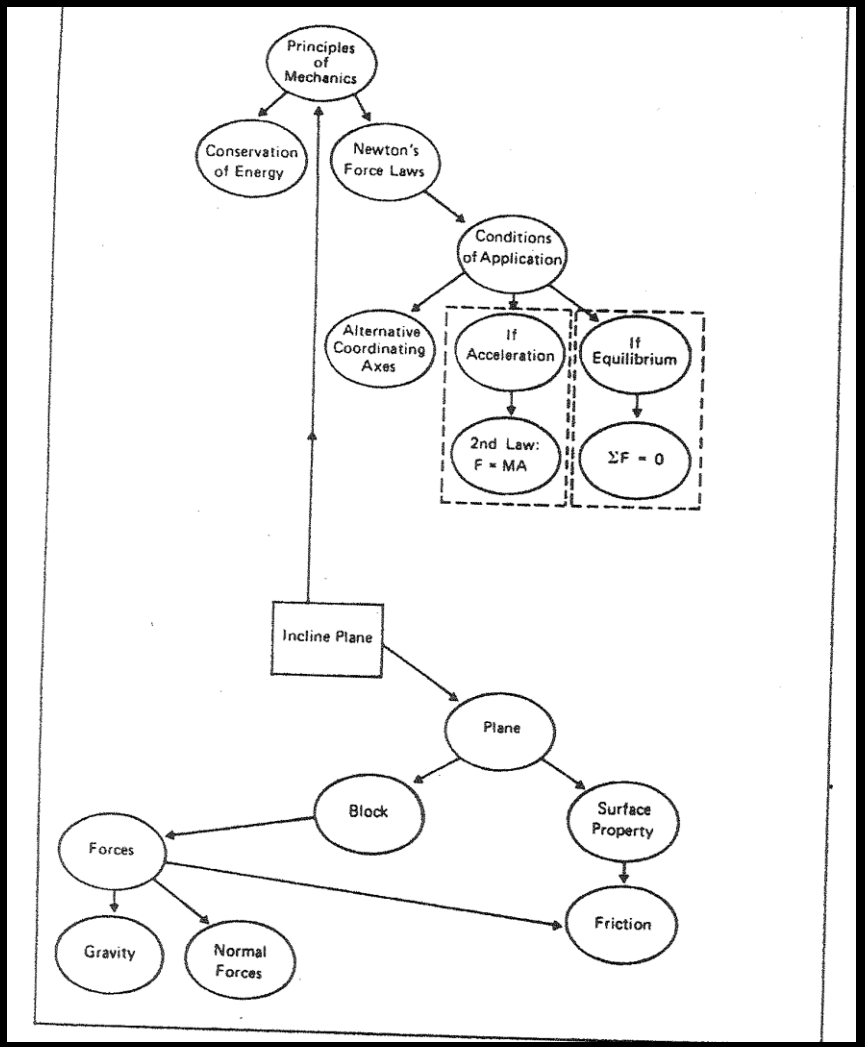
Expert 4: These can be done from energy considerations. Either you should know the principle of conservation of energy, or work is lost somewhere.

From Chi et al. (1982)

Three minute elaboration on the concept ‘inclined plane’



Novice



Expert

From Chi et al. (1982)

Medical Diagnosis

- Task of diagnosis *ill-defined*
  - Starting state, available means, and goal state often poorly specified
  - Vast number of possible symptoms and diseases
- Early studies on experienced doctors (e.g., Elstein et al., 1978)
  - Able to zone in on a few important hypotheses
  - Consideration of disease incidence (base rate) more common than underlying pathophysiological processes
  - Both reasoning forwards – from symptoms to diseases, and backwards – to gather new information

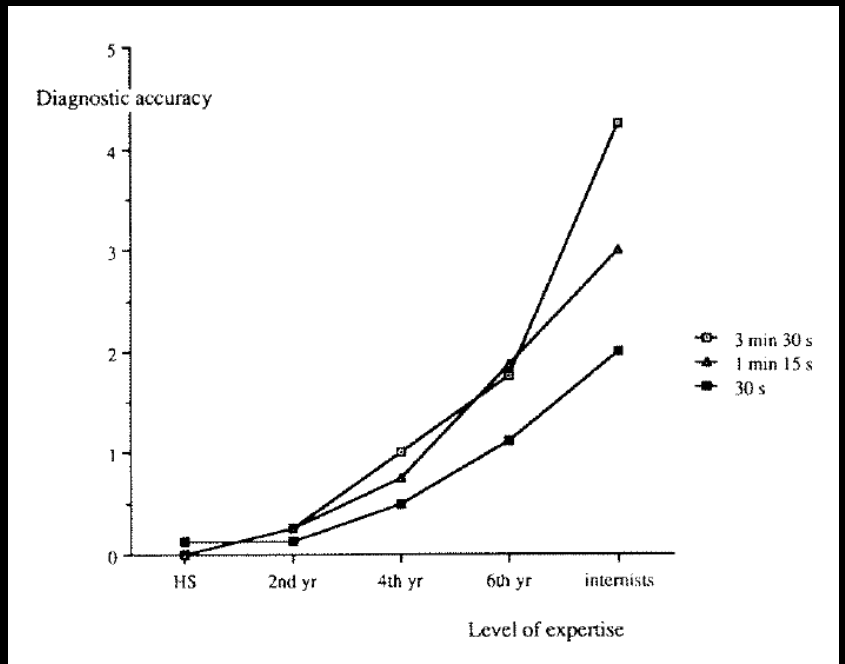
The intermediate effect

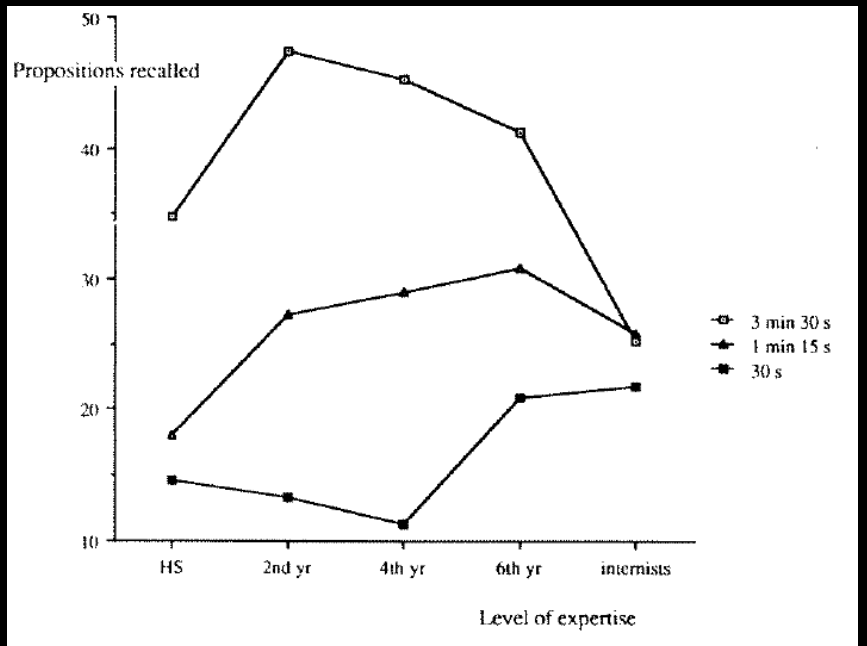
- Accuracy of diagnosis increases with expertise level
- But recall of information better for those at intermediate level
- Eg Schmidt & Boshuizen, 1993

-Subjects ranged from 1st yr students to internists

-Presented with case; recall text, make diagnosis & produce explanation

-Vary exposure time to text (3m30s, 1m15s, 30s)





The intermediate effect

- Explained in terms of different forms of knowledge for experts vs. intermediates or novices (not just more knowledge)

Novice	Lay knowledge and basic biology		
Intermediate	Extensive 'book-learning' of pathophysiology Eg causal links between diseases and symptoms	Elaborate and slow reasoning	Better recall of details except with short exposure
Expert	**Encapsulation** of knowledge through experience with actual cases Develop '**illness scripts**'	Faster reasoning less reference to explicit info	Recall of details poorer but unaffected by length of exposure

Illness scripts

- Illness scripts based on typical patient histories, relations between symptoms & diseases – encapsulated knowledge (Feltovich & Barrows, 1984)

Enabling conditions
(gender, age, smoking, travel, family history...)

Consequences
(Symptoms: Fever, pain...)

Fault
(e.g., invasion of tissue by pathogenic organisms...)

From van Schaik et al. (2005)

Multi-layered knowledge structures

- Experts use multi-layered knowledge structures
- Causal knowledge in terms of pathophysiology becomes encapsulated through experience leading to illness scripts
- However, causal knowledge does not become inaccessible
- Less need for elaborate reasoning in typical cases
- Is available for non-routine cases where illness scripts do not apply (Boshuizen, 1989)

Naturalistic decision making

See Phillips, Klein & Sieck (2004)

Naturalistic decision making

- How experts make real-world decisions in situations of uncertainty and time-pressure (Klein, 1998, 2009)
- Ill-structured problems, changing environments, competing goals
- Focus on high-stakes decisions – firefighting, military commanders, airline pilots …
- Use of field rather than lab studies
- Emphasizes role of cognitive processes such as pattern recognition and mental simulation

See Phillips, Klein & Sieck (2004)

Features of expertise (I)
(from Phillips, Klein & Sieck, 2004)

- *Perceptual skills* – ability to make fine discriminations and notice cues missed by novices
- *Mental models* – rich internal representations of how things work in domain of practice
- *Sense of typicality and associations* – large repertoire of complex patterns; recognize what is typical in situation & detect anomalies
- *Routines* – know how to get things done; large repertoire of tactics
- *Declarative knowledge* – know many facts and details

Features of expertise (II)
(from Phillips, Klein & Sieck, 2004)

- *Mental simulations* - Run simulations to generate predictions and expectations, and evaluate possible actions
- *Assessing situations* - Spend more time understanding dynamics of situations; spot anomalies and detect problems
- *Find leverage points* – generate novel actions by identifying and capitalizing on unapparent opportunities for useful interventions
- *Manage uncertainty* – range of strategies for handling uncertainty (e.g., filling in gaps with assumptions, mental simulation, seeking new information)
- *Self-monitoring* – better understanding of one's own strengths and limitations

Naturalistic decision making (example)

- Laundry chute fire

  A report of flames in basement of four-storey building is received at the fire station. The fire chief arrives at the building: there are no externally visible signs of fire, but a quick internal inspection reveals flames spreading up the laundry chute. That's straightforward: a vertical fire spreading upward, recently started – tackle it by spraying water down from above. The fire chief sends one unit to the first floor, one to the second. Both units report that the fire has passed them. Another check of the outside of the building reveals that now the fire has spread and smoke is filling the building. Now that the quick option for extinguishing the fire is no longer viable, the chief calls for more units and instigates a search and rescue – attention must now shift to establishing a safe evacuation route.
- Klein (1998) - in such scenarios experts do not make decisions in the traditional sense (eg generating set of options, selecting best one via maximizing etc)
- Experts often recognize/classify the situation and take an appropriate action without deliberation

Naturalistic decision making

- Expertise plays role in all three variations –
- Recognizing typical situations
- Constructing a plausible causal mental model or story
- Mental simulation of a course of action to evaluate it

Acquiring decision-making expertise

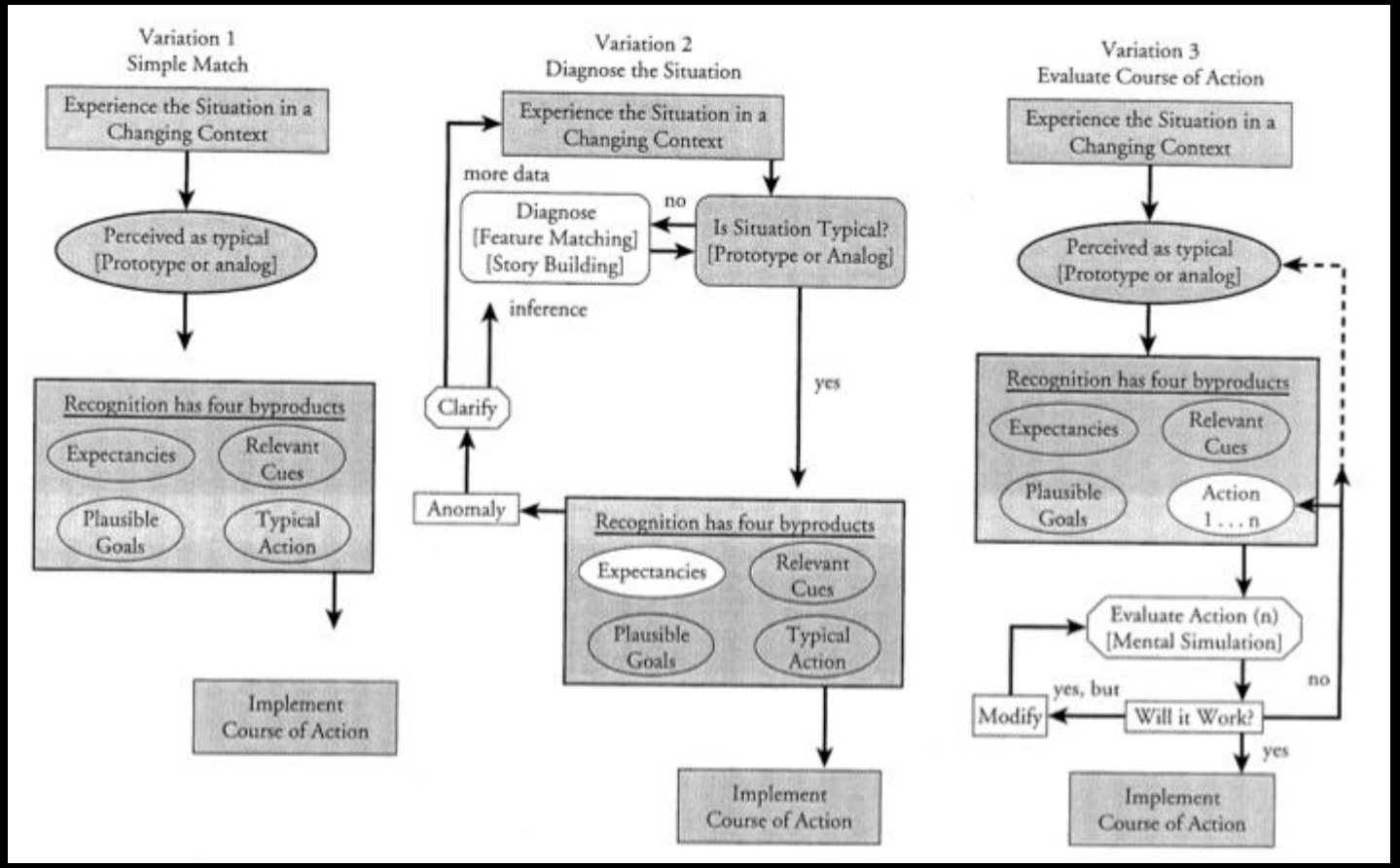
- Four ways that experts learn (Klein, 1998; Phillips, Klein & Sieck, 2004)
  - Engaging in deliberative practice , and setting specific goals and evaluation criteria
  - Compiling extensive experience banks
  - Obtaining feedback that is accurate, diagnostic and reasonably timely
  - Enriching their experiences by reviewing prior experiences to derive new insights and lessons from mistakes

Recognition-primed decision model

DM recognizes situation as prototypical - leads direct to action

Situation is unfamiliar/ambiguous. DM deliberates/gathers new data to generate assessment. Mental simulation used to construct plausible story

DM uses recognition to generate plausible action and uses mental simulation to evaluate action



Phillips et al., 2004

Thank you!

References

- Ericsson, K. A., Prietula, M. J., & Cokely, E. T. (2007). The making of an expert. *Harvard business review*, *85*(7/8), 114.
- Cambridge Handbook of Expertise and Expert Performance (Ericsson et al., 2006)
- Anders Ericsson, K., Roring, R. W., & Nandagopal, K. (2007). Giftedness and evidence for reproducibly superior performance: An account based on the expert performance framework. *High Ability Studies*, *18*(1), 3-56.
- Gobet, F., Lane, P. C., Croker, S., Cheng, P. C., Jones, G., Oliver, I., & Pine, J. M. (2001). Chunking mechanisms in human learning. *Trends in cognitive sciences*, *5*(6), 236-243.
- Gobet, F. (2005). Chunking models of expertise: Implications for education. *Applied Cognitive Psychology*, *19*(2), 183-204.