

How Cognitive Psychology Can Help Analogy-Based Project Estimation

Carolyn Mair

Southampton Solent University

Martin Shepperd

Brunel University

Mark Stephens

EDS



Research Project

“A Cognitive Perspective on Analogy-based Project Estimation”

Aim: to investigate cognitive processes of software professionals using CBR tools
to develop more effective support for estimators.

Funded by UK Government (EPSRC) in collaboration with EDS (2008-9).

Biographies (1)

Dr Carolyn Mair is a Senior Lecturer in Psychology at Southampton Solent University. She lectures in Cognitive Psychology and Psychobiology and her research interests are in cognitive processes.



carolyn.mair@solent.ac.uk
cazweb.info

Biographies (2)

Prof Martin Shepperd holds the Chair of Software technology at Brunel University. His research interests include software engineering and project cost modelling.

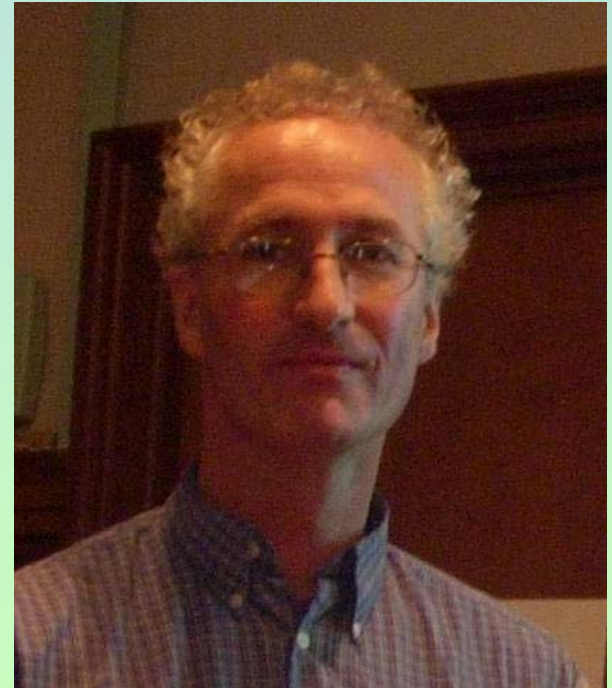
martin.shepperd@brunel.ac.uk
people.brunel.ac.uk/~csstmms



Biographies (3)



Dr Mark Stephens works for global outsourcer, EDS, as part of their Application Services Global Metrics Group. He has recently been involved with Estimation improvement initiatives, but has a keen interest in all metrics related disciplines.



Agenda

1. Scene setting
2. Cognitive psychology theories of problem solving
3. Human Analogical Problem Solving
4. Individual differences
5. Assessment and proposed outcomes
6. Summary

1. Scene setting

- Project cost (typically effort) estimation is example of infrequent, high-value problem solving
- Lack knowledge to produce immediate solution
- Typically humans use past experience when solving problems

“A problem is any given situation that differs from a desired goal”

2 groups of non-trivial, abstract problems

1 **Well-defined** problems

- clear goal state
- possible algorithmic solution
- finite set of operators (rules)

2 **Ill-defined** problems

- not clearly definable, but involve sub-problems that can be well-defined
- involve creativity

Knowledge-intensive tasks

- Semantically rich (Bhasker & Simon, 1977)
 - Domain-specific knowledge
 - Learned
- Formal (Larkin, 1981)
 - Great deal of knowledge
 - Depend on logical principles
 - Geometry versus Psychology
- Strategies, knowledge structures
- Novices – Intermediate – Experts

Defining the Problem

- We want *accurate* cost and schedule predictions for software projects at an *early* stage
- Repeatability (defined process)
- Rationale for prediction

But ...

- Dealing with complex, dynamical and open systems that are not well understood
- Trade-offs and constraints
- Attempts to find simple (or complex) predictive models not generally successful

Why use Expert Judgement?

Most widely used estimation technique
(Jorgensen, 2007)

No consistently 'best' automated prediction
system (Shepperd and Kadoda, 2001)

Lack of historical data

Need to 'own' the estimate

Experts plus ... ?

Problems with Expert Judgement

Objectivity

Repeatability

Recall /awareness

Not enough experts!

What's the problem?

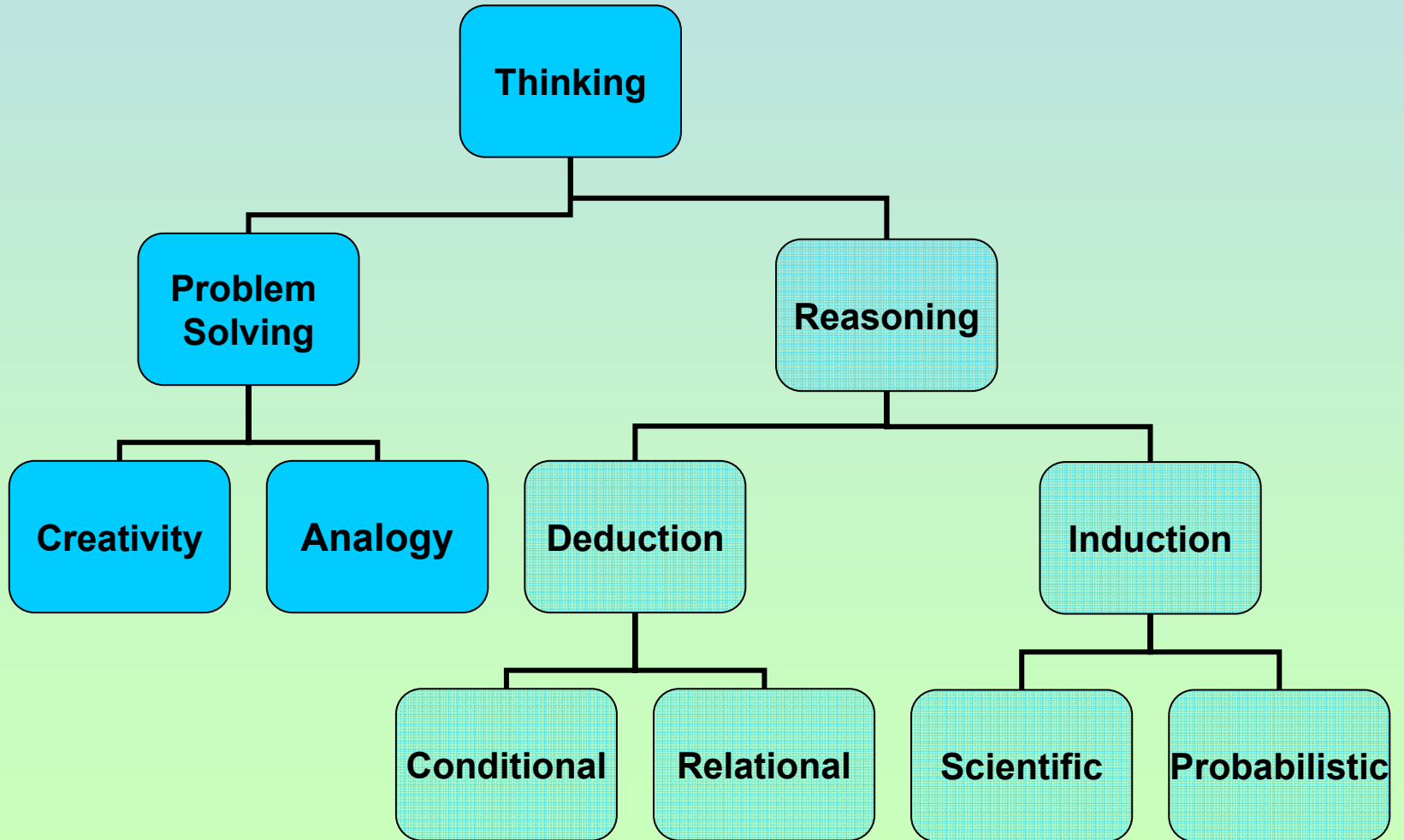
- Don't have all answers (yet!)
- Why is project estimation not accurate
- Experts problematic
- CBR problematic
- Experts + CBR = more accurate, but imperfect estimate

- Human problem-solving no longer black box
- Cognitive science

2. Cognitive psychology theories of problem solving

- Many theories
- To what extent are these theories applicable to experts using CBR in 'real world'?

Thinking hierarchy



3. Human Analogical Problem Solving

- Chen
- Gick and Holyoak
- Ohlsson
- Gentner et al.

- Anderson (general computational model)

Analogical Problem Solving

Chen (2002)

Main types of similarity between problems

- Superficial similarity
- Structural similarity
- Procedural similarity

Analogical Problem Solving

Gick and Holyoak (1980)

- Gick and Holyoak (1980)

Representational Change Theory

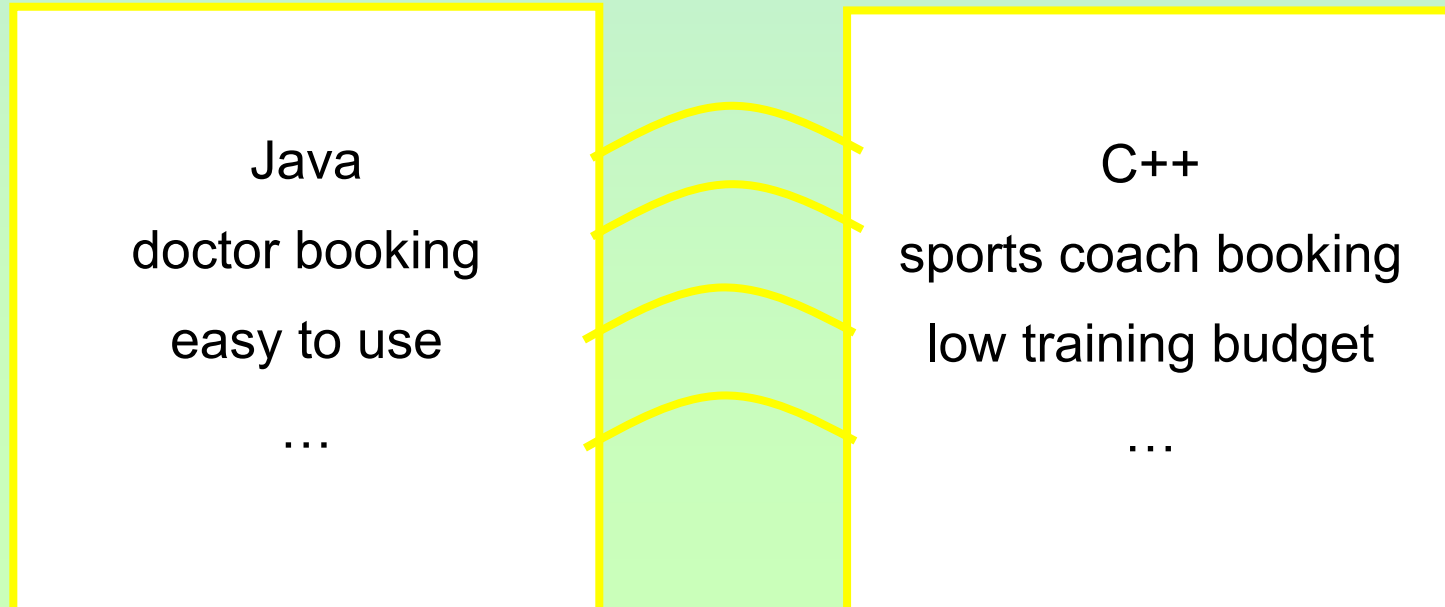
Ohlsson (1992)

- A problem occurs when the problem is represented in a way that does not permit retrieval of the necessary operators or possible actions
- The impasse is broken when the problem representation is changed

Structure Mapping Theory

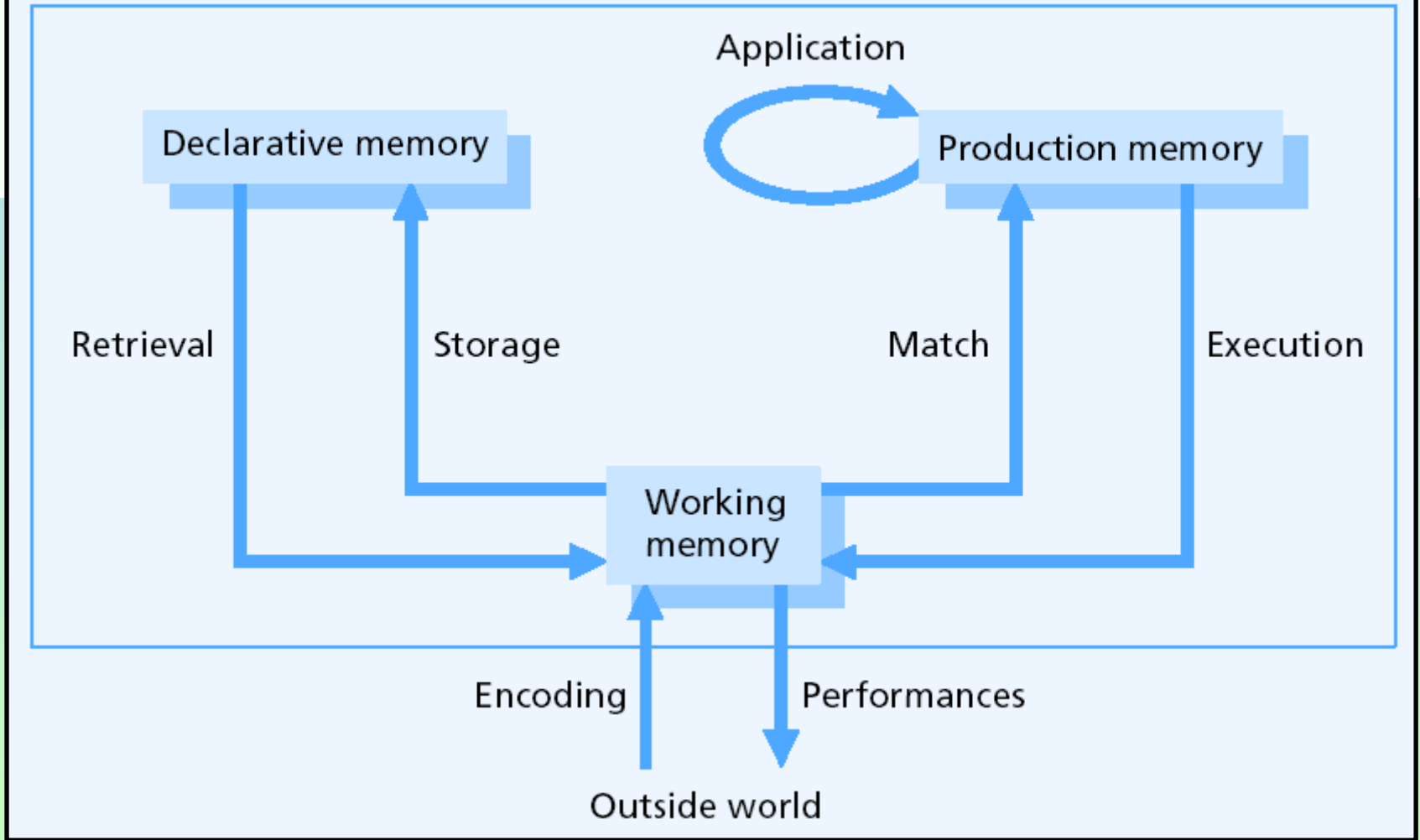
Gentner, 1983; Gentner et al., 2001

- Influential theory using analogies in problem solving
- People produce mapping between target and analogical problem
- This is structural alignment



Anderson's ACT-R (e.g., 1983, 1990, 1993, 1996)

- Anderson Adaptive Control of Thought
- General Principle of Rationality
- “The cognitive system operates at all times to optimise the adaptation of the behaviour of the organism” Anderson (1990, p. 28)



Schematic diagram of major components and interlinking processes in Anderson's (1983, 1993) ACT models.
(Source: Eysenck and Keane 2007)

ACT-R Evaluation

- Good experimental support
- Limitations
 - innate ability may be important
 - those with innate ability might be willing to practice as required
 - effects of deliberate practice may be domain specific

Analogical Problem-solving Evaluation

Reasonable evidence for superficial, structural, and procedural similarity between past and current problems, but, problems:

- similarities between problems in everyday life less obvious
- people choose structural rather than superficial similarities
- individual differences have been under-researched

4. Individual Differences

- Personality characteristics and traits
- Differences in performance
- Stanovich and West (1998a, 2000)
Individual differences in reasoning performance

Dual-system Theory

Evans (2003)

- System 1
 - Rapid, parallel, and automatic processes
- System 2 processes
 - Slow and serial in nature

Most individual differences may occur in System 2 rather than System 1

Evidence for Dual-system Theory

- Use of System 2 logic is less prone to belief-bias effect
- Confirmed by Stanovich and West (1998)
- Goel and Dolan (2003) fMRI evidence for existence of 2 systems in thinking

Evaluation

- Convincing evidence for theory, but...
- Limitations of theory
 - Vagueness
 - How different are the systems?
 - How do they interact?
- Theory may not capture richness of human reasoning ability

5. Assessment and proposed outcomes

- Improved understanding, and utilization, of analogy-based project estimation tools (CBR)
- Recommendations for more effective CBR tools
- Follow up project to develop tools based on knowledge and evidence from Cognitive Science

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