Multiple Processes in Graph-based Reasoning

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DRKA Project

Four goals:

1. *Empirical investigation* of cognitive processes and factors involved in graph-based reasoning
2. Construct a *conceptual framework* to analyse the complex cognition that occurs when people interact with graphs
3. Develop a *graph drawing tool* for Knowledge Acquistition to allow experts to represent their knowledge in graph form
4. Use conceptual framework and results of empirical studies to provide a set of *principles and guidelines* for knowledge engineers using graph tool in DKA interviews

Overview

1. (a) Previously proposed process models of graph comprehension

(b) limitations of the models

2. Reasons for our approach

3. Experiment & Results

4. Graph-based Reasoning (GBR) model

5. Example

Previous Research

- **Diagrammatic representations:**

  e.g. **Larkin & Simon (1987)** — Informationally equivalent representations can require very different amounts of computation

- **Graph models:**

  Simkin & Hastie (1987) — Experimental comparison of bar charts *v* pie charts. Specification of component processes

  Pinker (1990) — Graph knowledge embodied in *graph schemas*. Proposed mechanisms for knowledge encoding & retrievel during graph comprehension

  Lohse (1993) — Simulated simple question answering processes

  Carpenter & Shah (1998) — Graph comprehension = *cycles* of visual encoding and interpretation

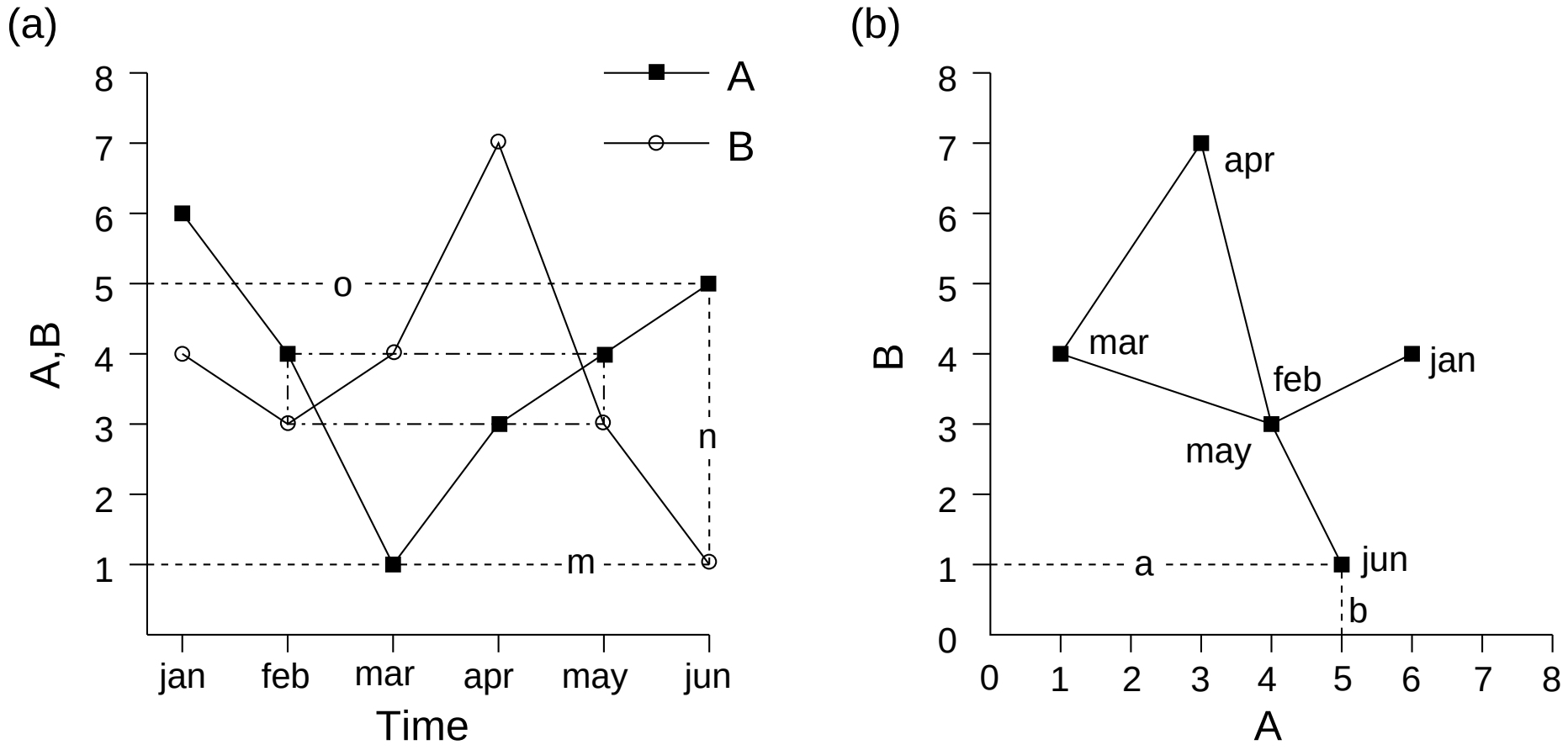
Limitations of Previous Graph Models

1. Range of processes and/or phenomena

- **(a)** Consider a variety of processes without detailed specification
- **(b)** Consider a restricted number of processes in detail
- **(c)** Focus on graph *comprehension*, not graph-based reasoning
- **(d)** Little explicit consideration of the conditions under which different types of processes operate

2. Choice of representations studied

- **(a)** Using one type of graph restricts the amount of behavioural variety that can occur
- **(b)** Using different classes of representation (e.g. pie charts *v* histograms) — difficult to generalise over behaviours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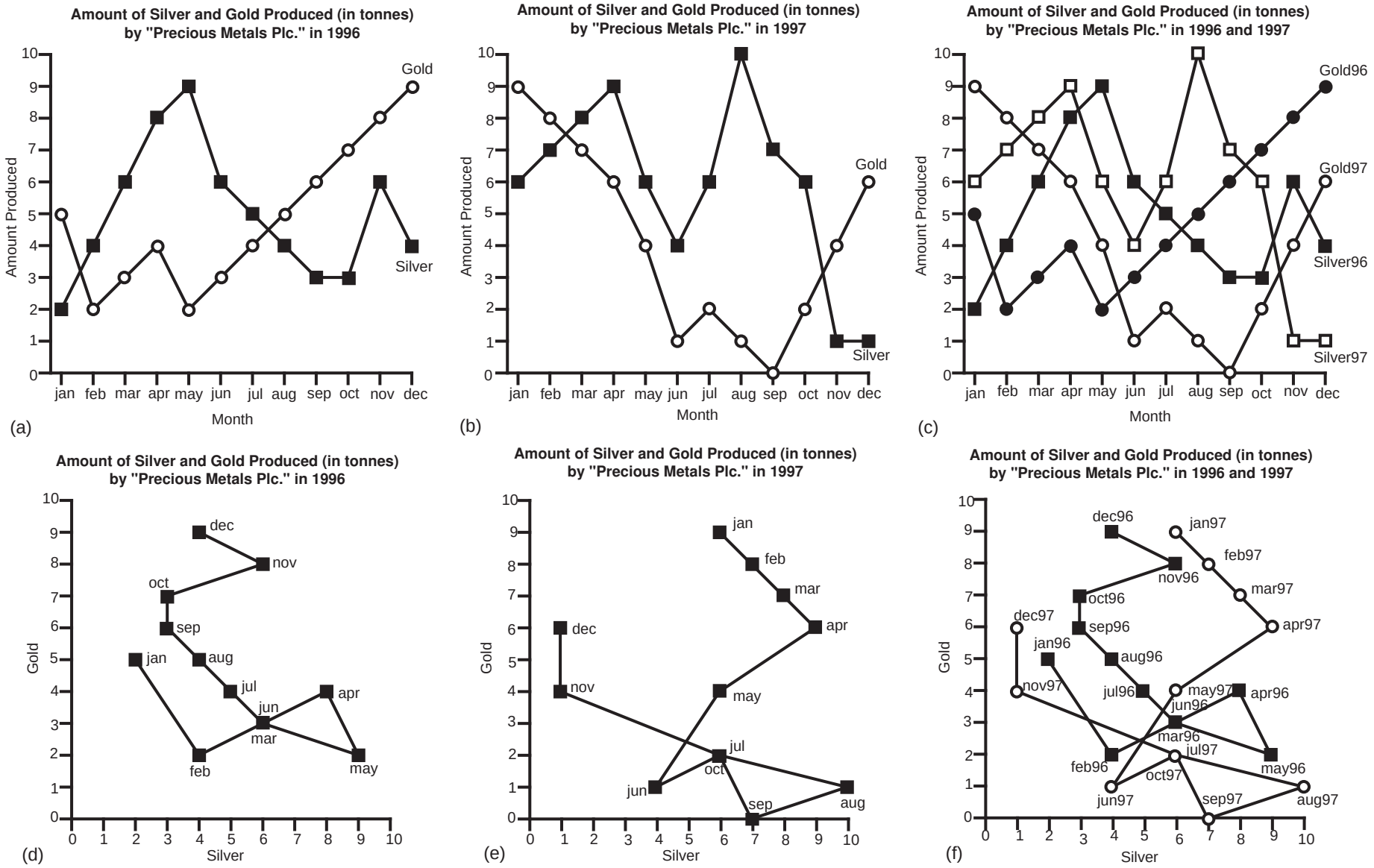

Amount of Silver and Gold Produced (in tonnes) by "Precious Metals Plc." in 1996
Amount Produced
Month
Gold
Silver
jan feb mar apr may jun jul aug sep oct nov dec
(a)
Amount of Silver and Gold Produced (in tonnes) by "Precious Metals Plc." in 1997
Amount Produced
Month
Gold
Silver
jan feb mar apr may jun jul aug sep oct nov dec
(b)
Amount of Silver and Gold Produced (in tonnes) by "Precious Metals Plc." in 1996 and 1997
Amount Produced
Month
Gold96
Gold97
Silver96
Silver97
jan feb mar apr may jun jul aug sep oct nov dec
(c)
Amount of Silver and Gold Produced (in tonnes) by "Precious Metals Plc." in 1996
Gold
Silver
dec nov oct sep jan aug jul jun apr mar feb may
(d)
Amount of Silver and Gold Produced (in tonnes) by "Precious Metals Plc." in 1997
Gold
Silver
jan feb mar apr dec nov may jul oct jun sep aug
(e)
Amount of Silver and Gold Produced (in tonnes) by "Precious Metals Plc." in 1996 and 1997
Gold
Silver
dec96 jan97 feb97 nov96 mar97 oct96 dec97 apr97 sep96 jan96 aug96 nov97 jul96 may97 apr96 jun96 mar96 jul97 feb96 may96 oct97 jun97 sep97 aug97
(f)

Example Questions

Q1. In which month in [1996/1997] does a reversal in the trend of both Silver and Gold production occur?

Q2. In which month in [1996/1997] does the largest absolute difference in the production of Silver and Gold occur?

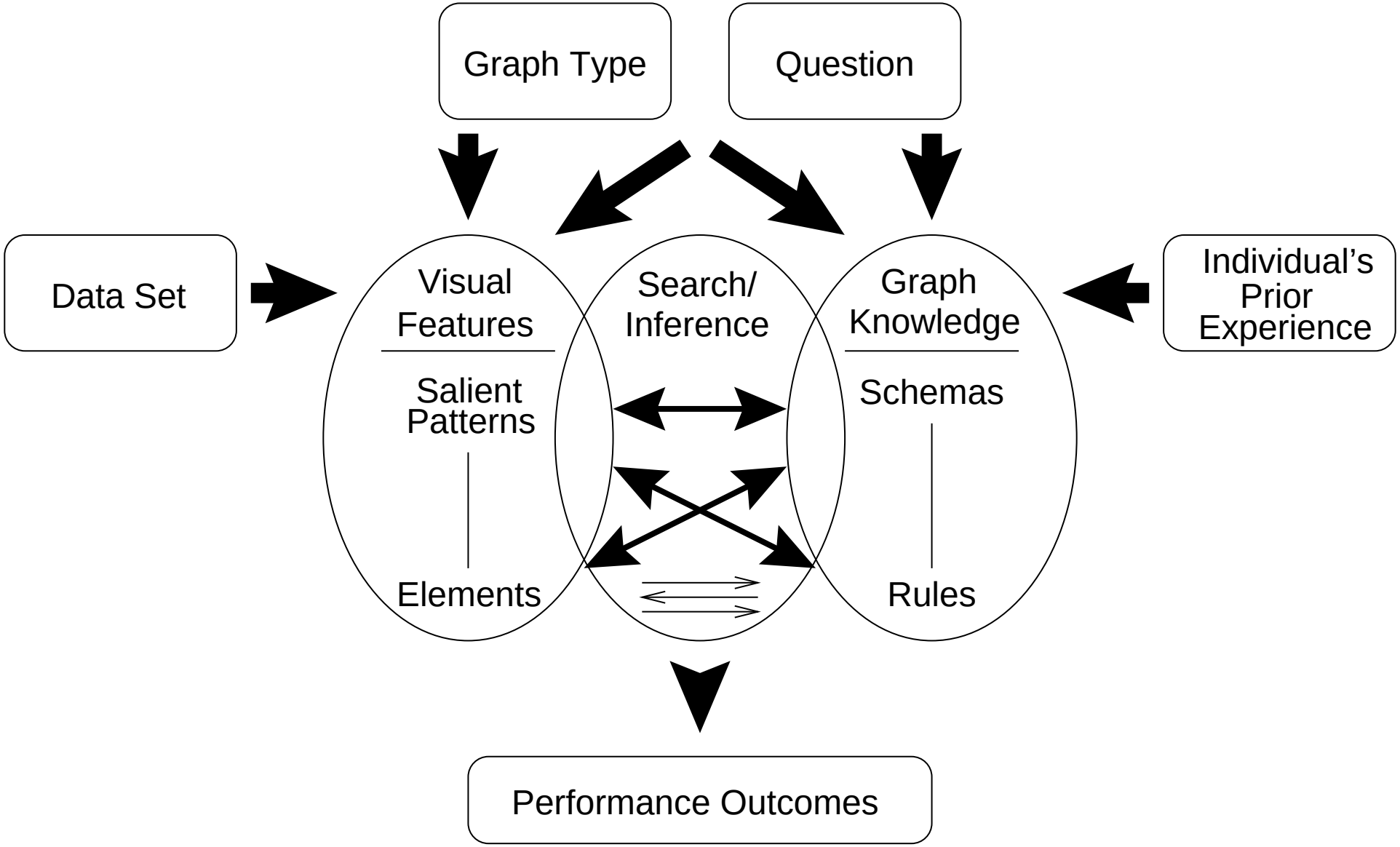
Q3. Which two months in [1996/1997] have amounts of Silver production which are exactly the same and also amounts of Gold production which are exactly the same?

Q4. In [1996/1997], when the amount of Gold production is 4, what is the amount of Silver production?

Q5. How many months in [1996/1997] is there a difference between Silver and Gold production of exactly 1 tonne?

Results

- Significant main effects on response accuracy and latency of:
  - Graph type
  - Question
- Significant interactions between:
  - Graph type & Graph complexity
  - Graph type & Question
  - Graph complexity & Question
  - Graph type & Graph complexity & Question
- Several factors interacting. How can we analyse these complex interactions?


Graph Type
Question
Data Set
Visual Features
Salient Patterns
Elements
Search/ Inference
Graph Knowledge
Schemas
Rules
Individual's Prior Experience
Performance Outcomes

Example: Questions 12 & 13

Q12: "In which month in 1996 was the greatest total amount of metal (i.e. both *Silver* and *Gold*) produced?"

Q13: "In which year was the most metal (i.e. both *Silver* and *Gold*) produced in any month?"

	Question 12		Question 13	
	Function	Parametric	Function	Parametric
CR	.938	.875	.800	1.00
RT	36.84	26.98	54.46	25.43

Proportion of correct responses (CR) and mean response time (RT in seconds) for each condition