The "Physics" of Notations: Towards a Scientific Basis for Constructing Visual Notations in Software engineering

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2009

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Introduction

- Visual Languages

Cave art – Lascaux cave,
France ~17.300 years old

Introduction

- Anatomy of visual language
  - Graphical symbols
  - Compositional rules

    Visual syntax
  - Definitions of symbols
    - 1D (lines), 2D (areas), 3D (volumes), text (labels), spatial relationships

Introduction

- What makes a good visual notation?

Introduction

- What makes a good visual notation?

Cognitive effectiveness

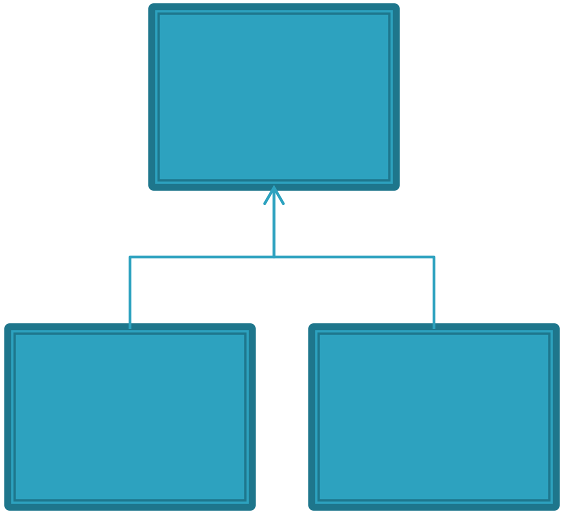
speed, *ease* and *accuracy* with which the human mind processes

A visual notation must

a. Effectively communicate with business stakeholders
b. Support design and problem solving by sw engineers

Introduction

- It’s location location location baby.



VS

The same? Different?
What is intuitive?

Introduction

- Visual dialects

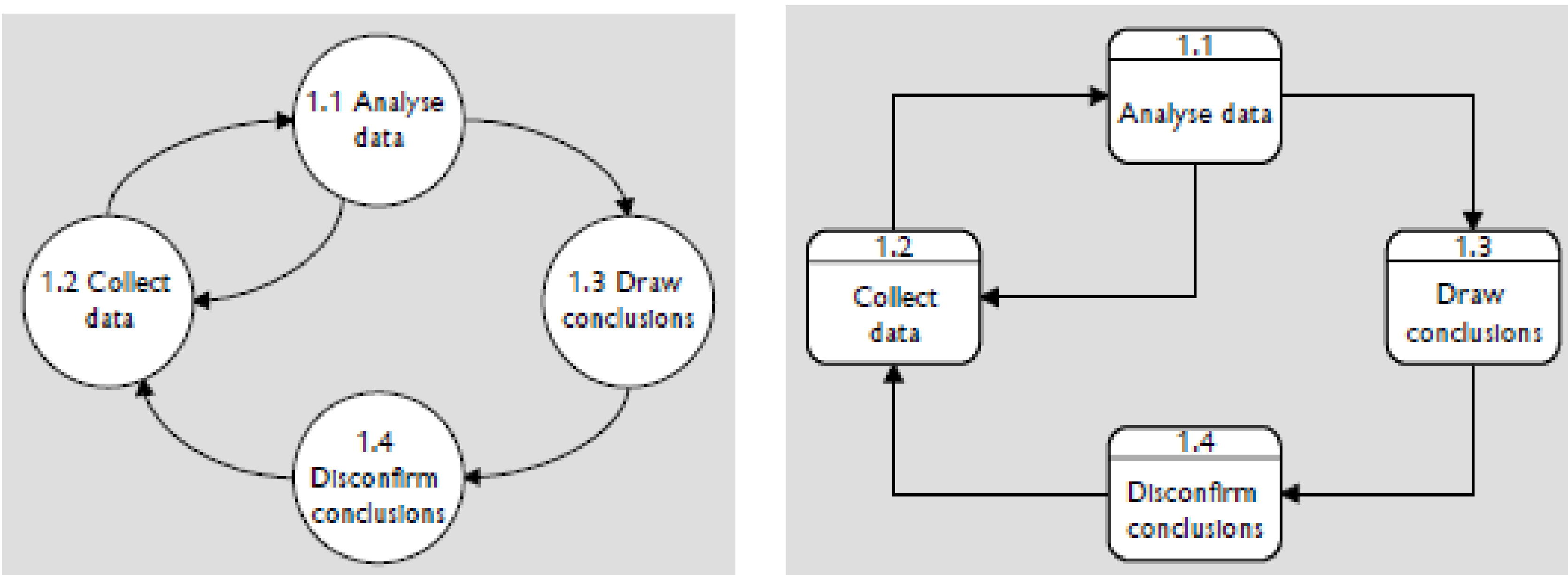


Figure 2. Visual Dialects: De Marco DFDs vs Gane & Sarson DFDs. Same semantics, different visual syntax: which is best?

Introduction

- Visual dialects

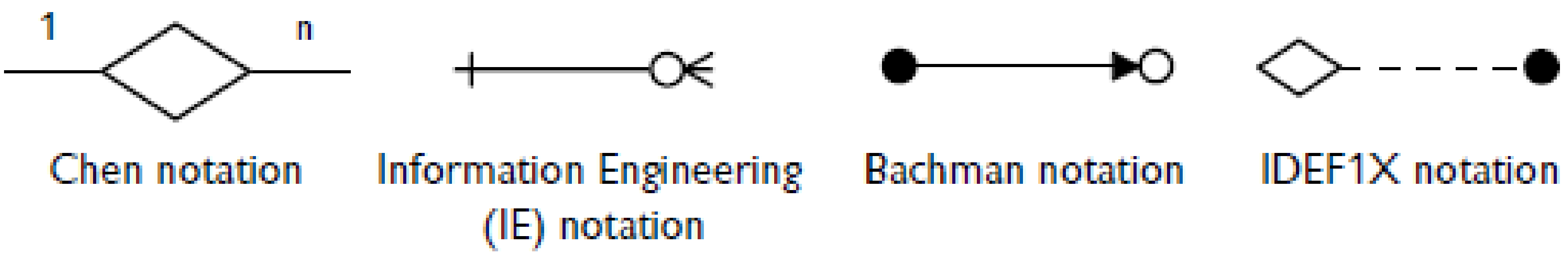


Figure 3. Semantically equivalent forms of the ER Model. All these visual forms express the same underlying relationship semantics.

Descriptive Theory

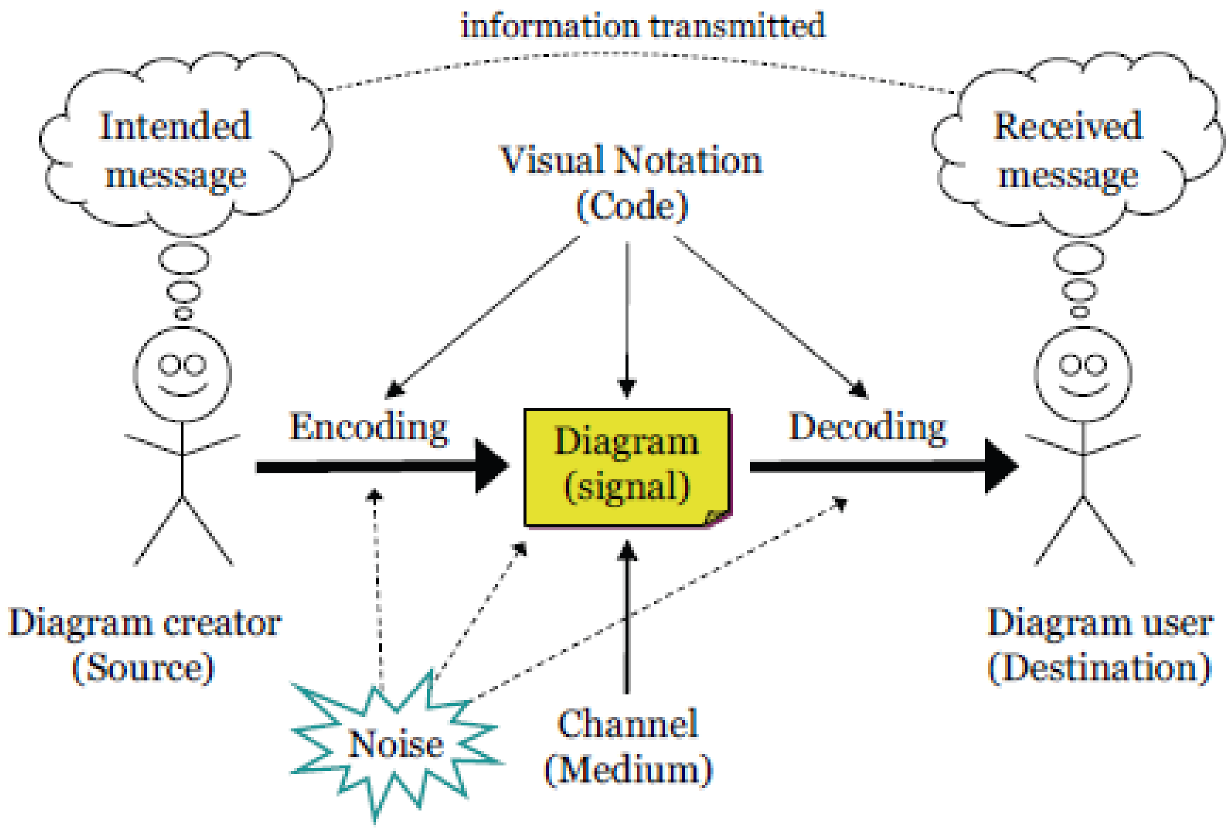


Figure 6. Theory of Diagrammatic Communication: communication consists of two complementary processes: encoding and decoding.

Descriptive Theory

- Design space

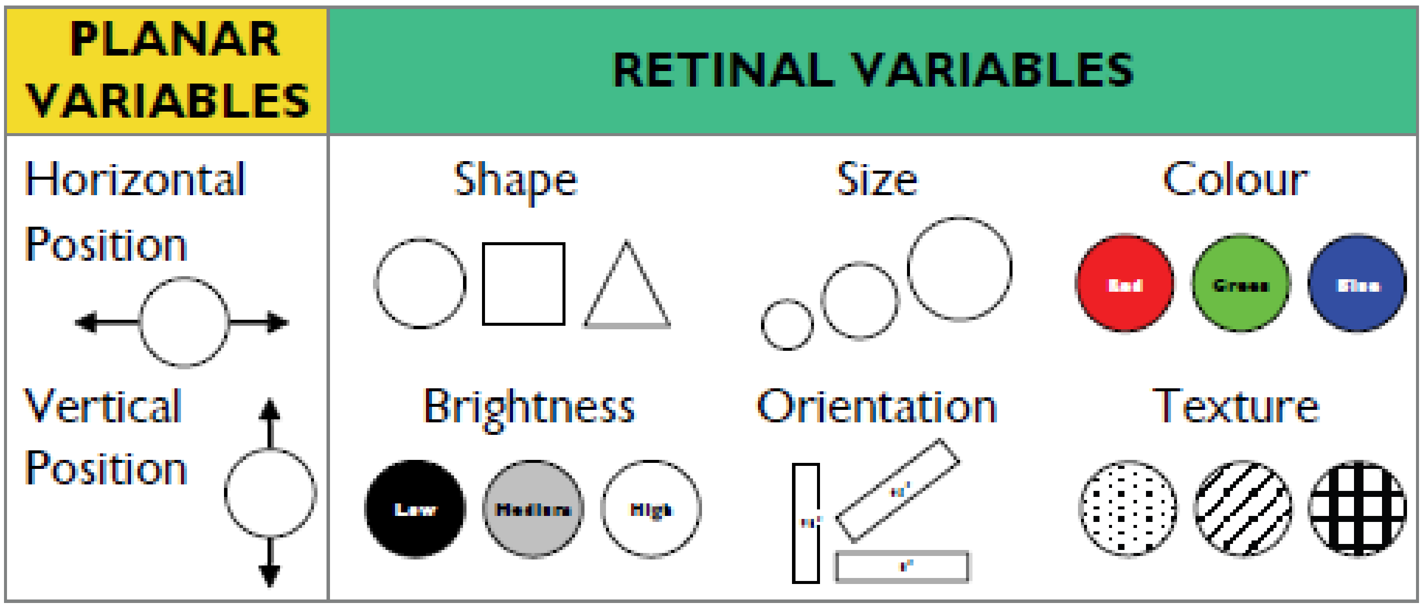


Figure 7. Visual Variables [8]: these define a set of elementary graphical techniques for constructing visual notations[3]

Descriptive Theory

- Design Space
  - Primary Notation
    - Formal definition. Set of symbols with prescribed meanings
  - Secondary Notation
    - Visual variables (reinforcive or claritive nature)
  - Visual Noise
    - Accidental secondary notation (result in distortion of intended message)

Descriptive Theory

- Solution Space
- Human graphical information processing

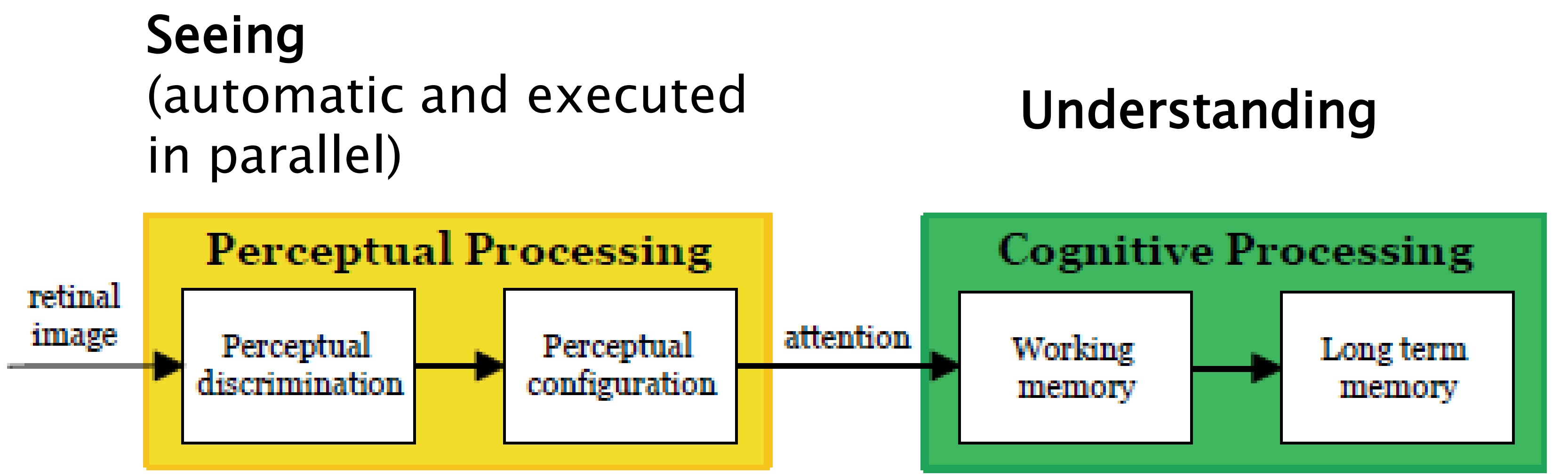


Figure 8. The Solution Space: maximising cognitive effectiveness means optimising notations for processing by the human mind

Prescriptive Theory

Each principle has:

- Name
- Semantic definition
- Operational definition
- Design strategies
- Exemplars and counter exemplars

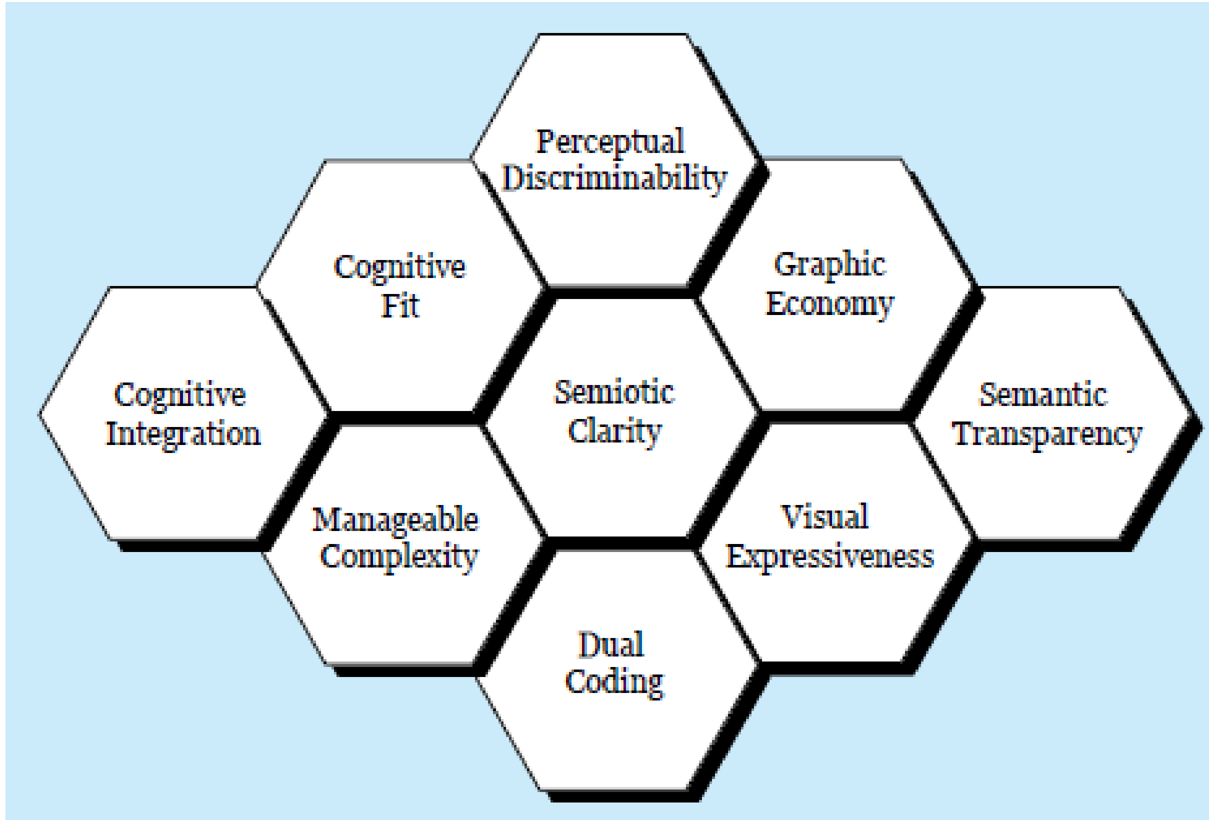


Figure 9. Principles for designing cognitively effective visual notations: the modular ("honeycomb") structure supports modifications and extensions to the principles

Prescriptive Theory

1. Semiotic Clarity

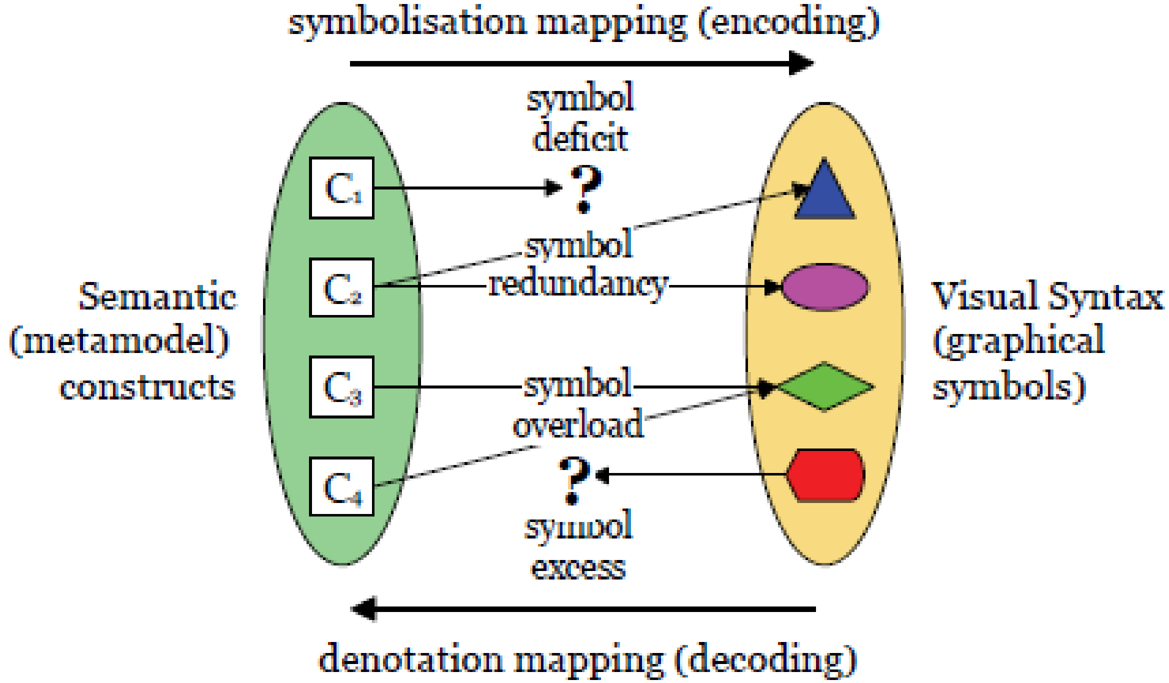


Figure 10. Semiotic Clarity: there should be a 1:1 correspondence between semantic constructs and graphical symbols.

Prescriptive Theory

Symbol Redundancy: multiple graphical symbols represent same semantic construct

Figure 11. Symbol redundancy (synographs) in UML: there are alternative graphical symbols for interfaces on Class Diagrams (left) and package relationships on Package Diagrams (right).

Prescriptive Theory

Symbol Overload: different constructs are represented by the same symbol (ambiguity)

Figure 12. Symbol Overload (homographs) in ArchiMate: the same graphical convention can be used to represent different types of relationships: generalisation (left) and composition (right)

Prescriptive Theory

Symbol Excess: symbols don’t correspond to semantic constructs

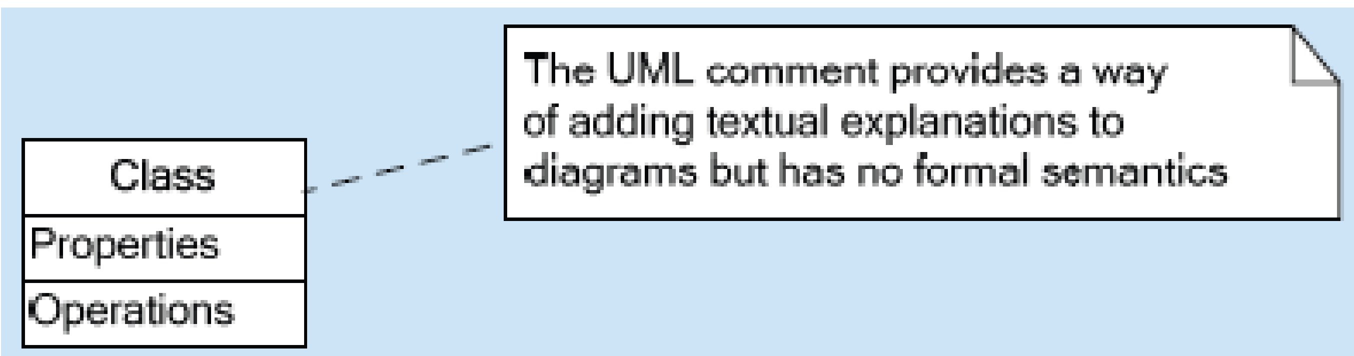


Figure 13. Symbol Excess in UML: the comment is a useful notational feature but should not be shown using a graphical symbol.

Prescriptive Theory

Symbol Deficit: semantic constructs are not represented by symbols

?

Prescriptive Theory

2. Perceptual Discriminability

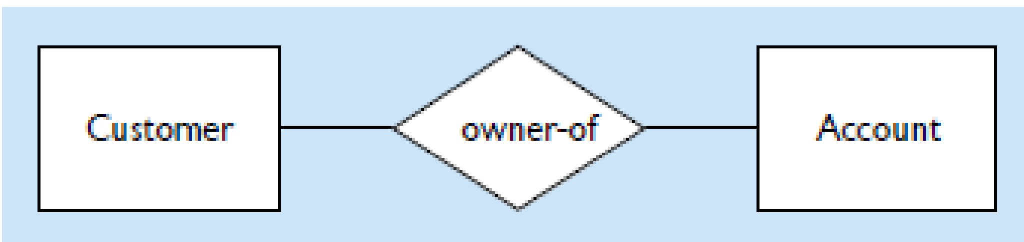
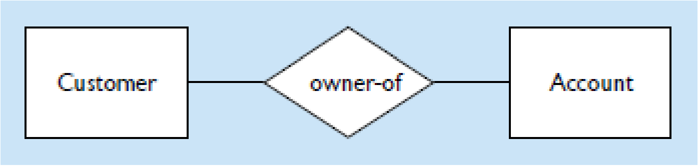


Figure 14. Experimental studies show that rectangles and diamonds in ER diagrams are frequently confused by novices

Prescriptive Theory

2. Perceptual Discriminability



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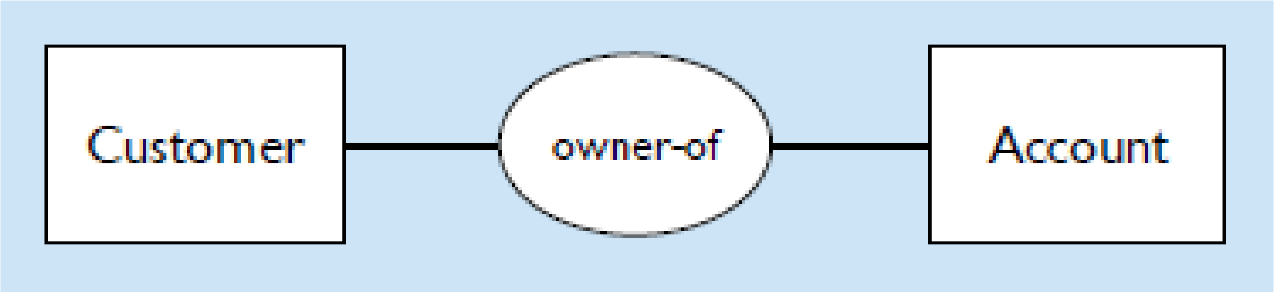


Figure 15. Entities and relationships could be made more discriminable by using shapes from different families

Prescriptive Theory

2. Perceptual Discriminability

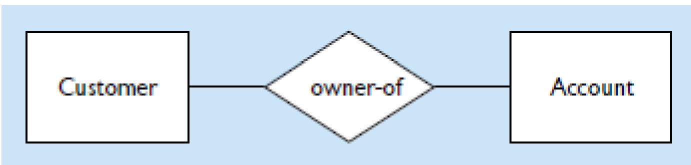


Figure 14. E
in ER diagra

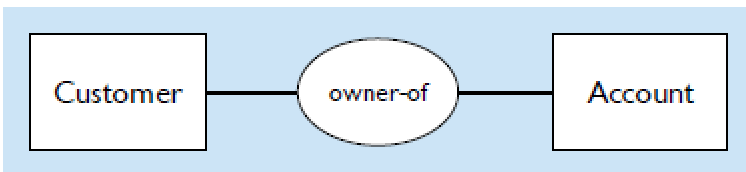


Figure 15. E
discriminabl

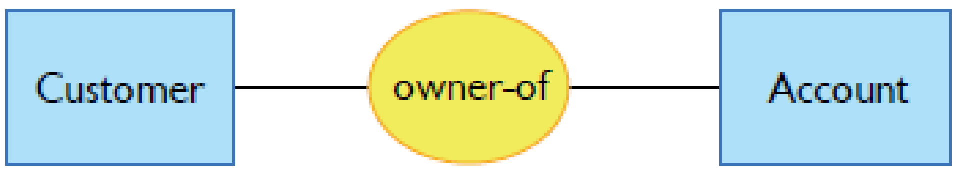
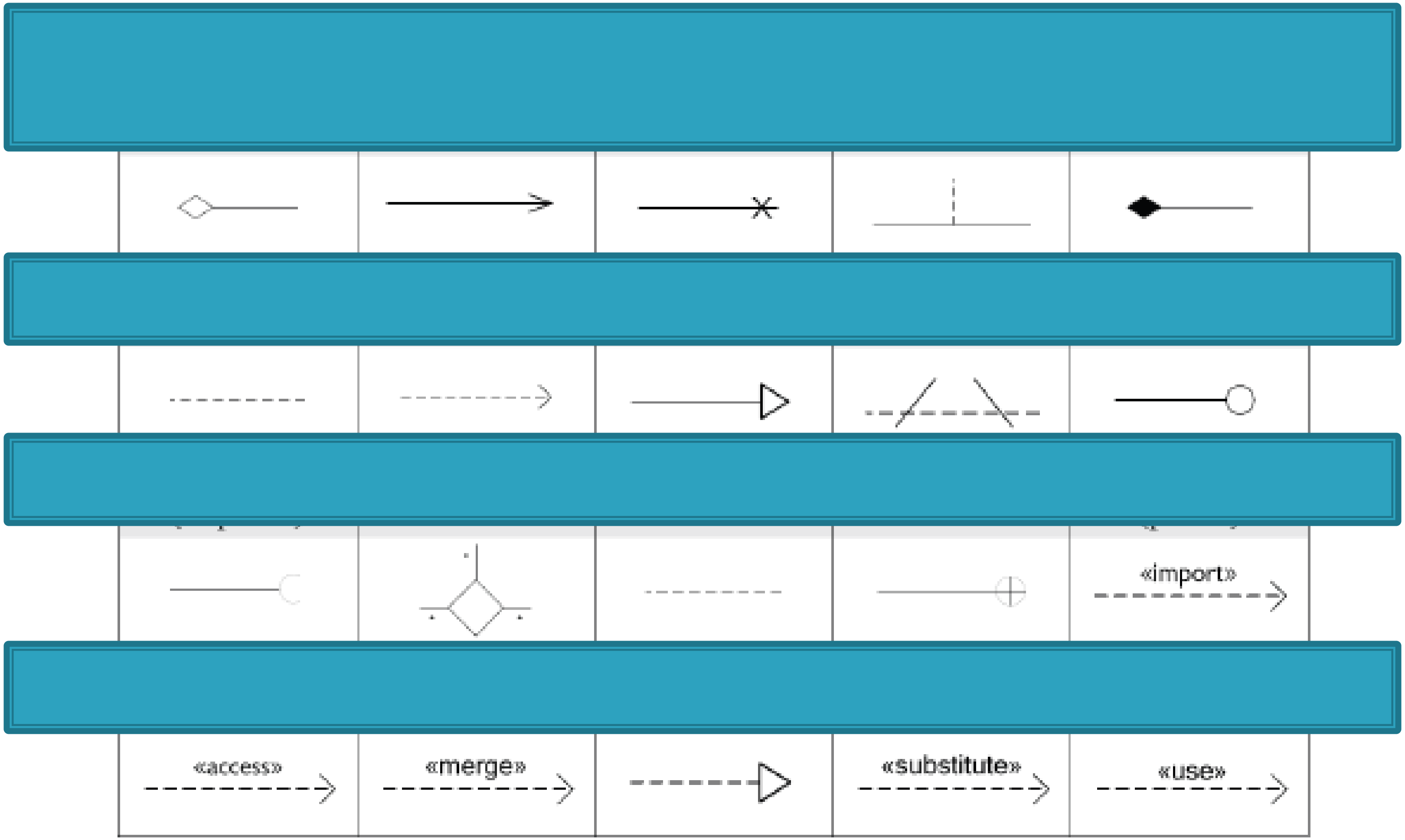


Figure 17. Redundant Coding: using multiple visual variables (shape + colour) to distinguish between symbols

Prescriptive Theory



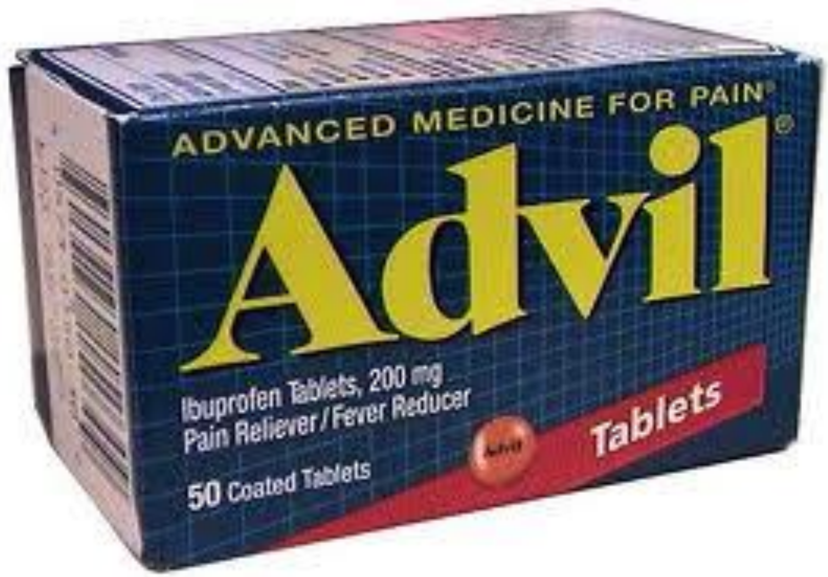
Prescriptive Theory

Table 1. Relationship Types on UML Class Diagrams

Aggregation	Association (navigable)	Association (non-navigable)	Association class relationship	Composition
Constraint	Dependency	Generalisation	Generalisation set	Interface (provided)
Interface (required)	N-ary association	Note reference	Package containment	Package import (public)
				«import»
Package import (private)	Package merge	Realisation	Substitution	Usage
«access»	«merge»		«substitute»	«use»

Prescriptive Theory

- Can I get you one of these?



Prescriptive Theory

2. Perceptual Discriminability

Figure 18. Textual Differentiation: UML uses labels and typographical characteristics to distinguish between symbols.

Prescriptive Theory

3. Semantic Transparency

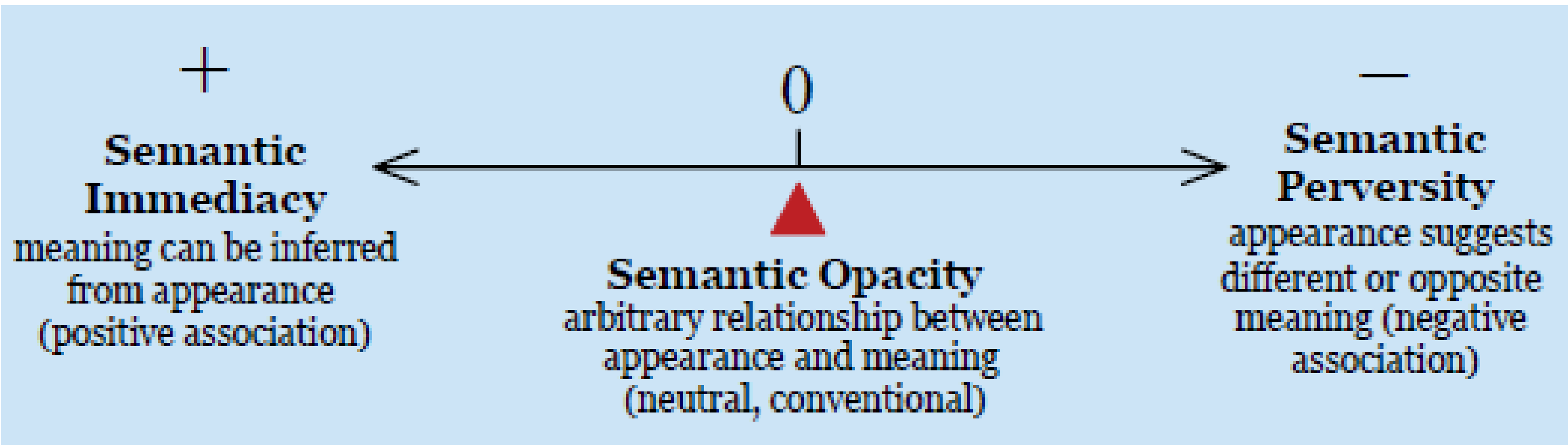


Figure 19. Semantic Transparency defines the degree of association between a symbol's form and its content

Prescriptive Theory

3. Semantic Transparency

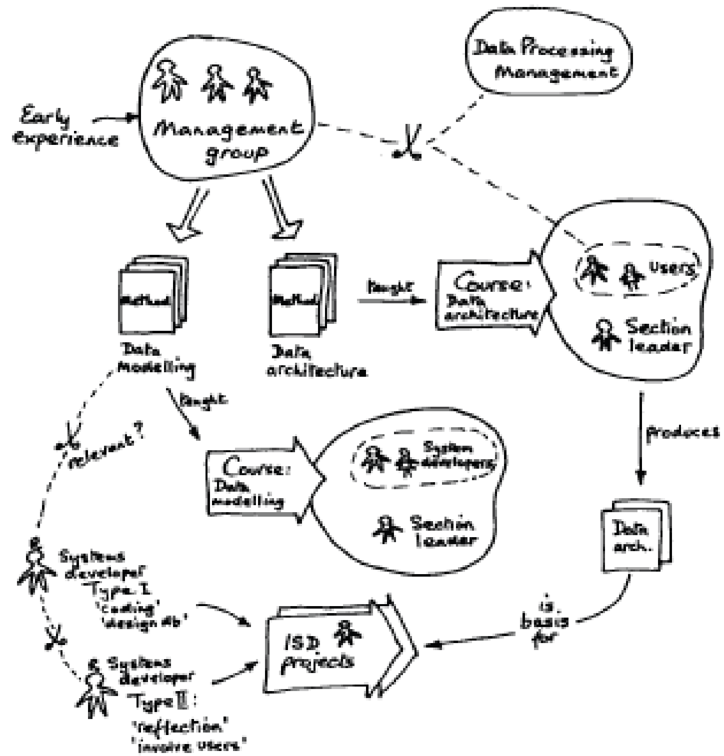


Figure 20. Rich pictures: a rare but highly effective example of iconic representation in SE [17]

Prescriptive Theory

3. Semantic Transparency

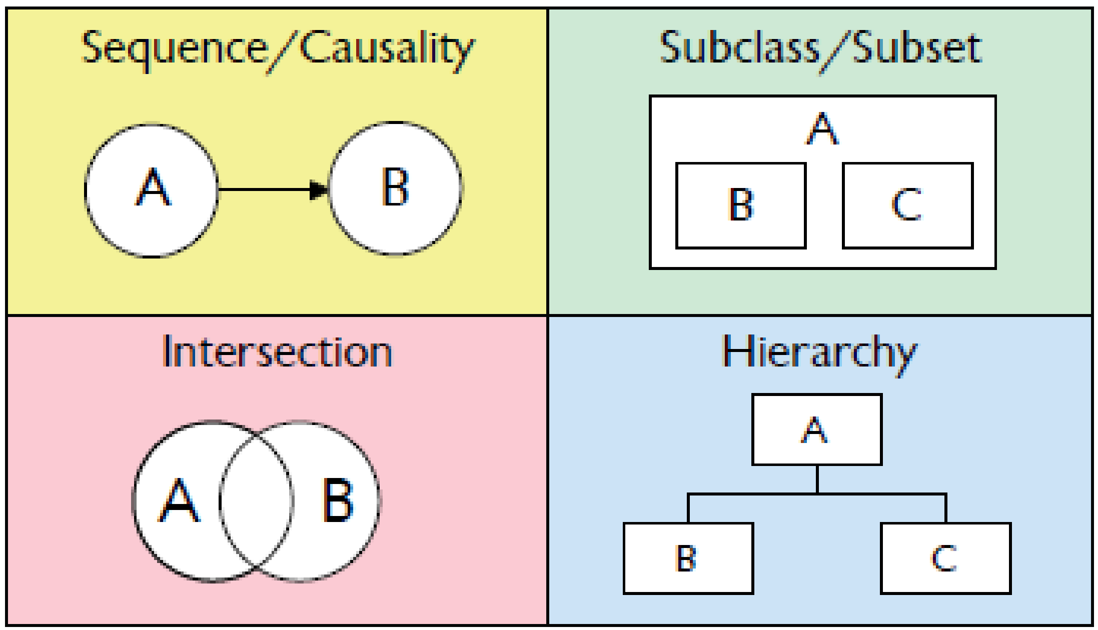


Figure 21. Semantically transparent relationships: these spatial relationships are interpreted in a spontaneous or natural way [147]

Prescriptive Theory

3. Semantic Transparency

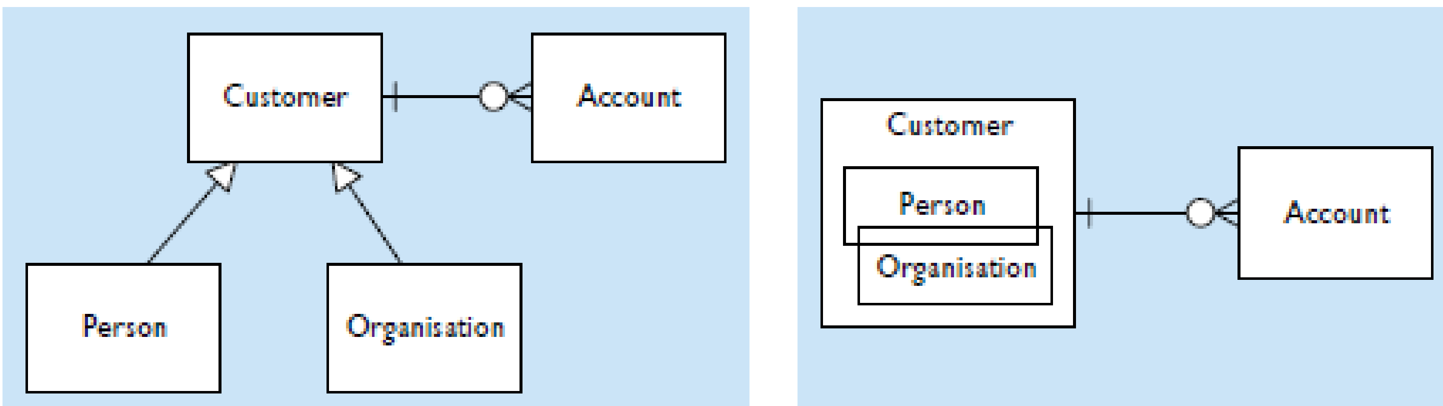


Figure 22. Spatial enclosure and overlap (right) convey the concept of overlapping subtypes in a more semantically transparent way than arrows (left).

Prescriptive Theory

4. Complexity Management

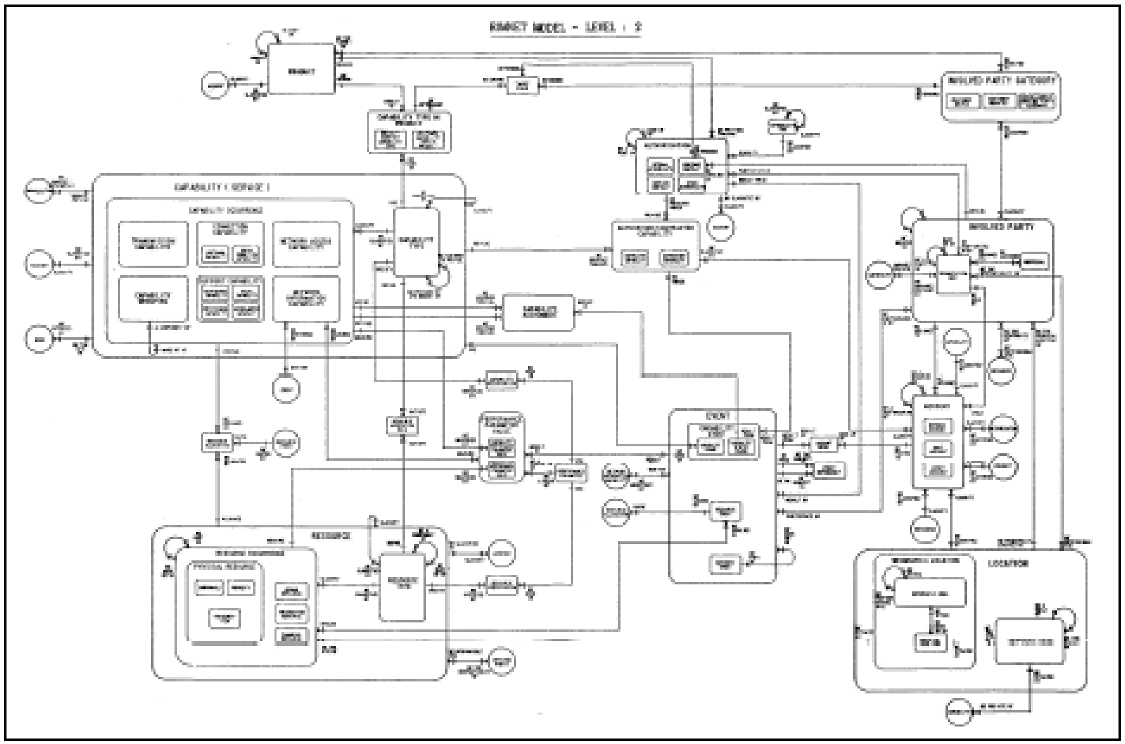


Figure 23. In the absence of complexity management mechanisms, ER models must be shown as single monolithic diagrams.

Prescriptive Theory

4. Complexity Management

Prescriptive Theory

4. Complexity Management

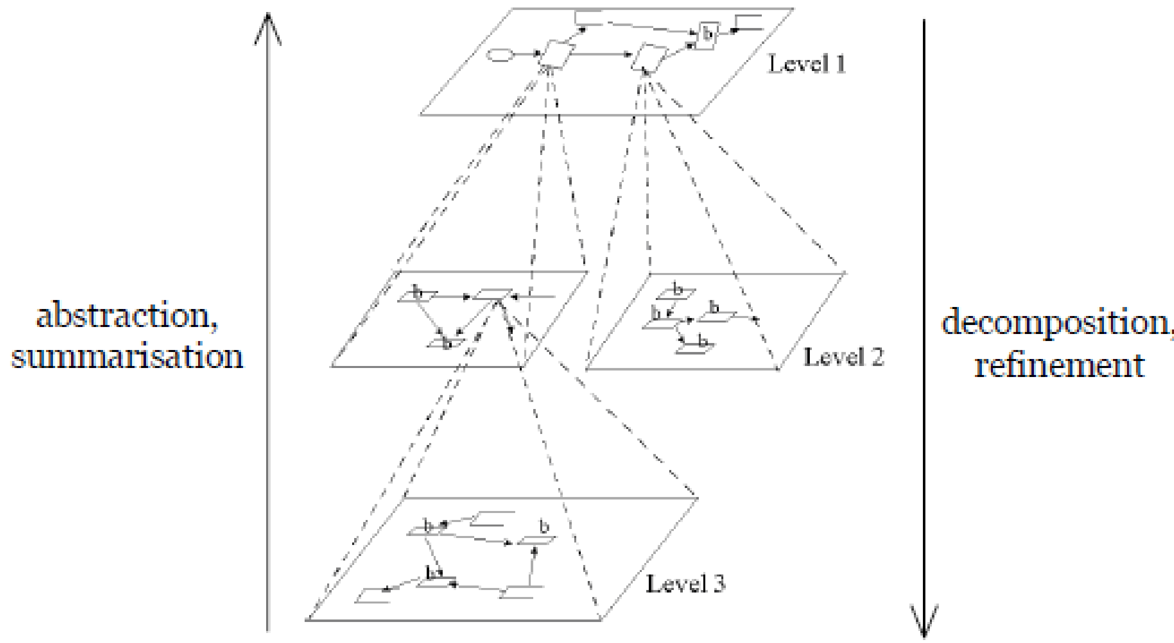


Figure 24. Hierarchical organisation allows a system to be represented at multiple levels of abstraction, with complexity manageable at each level

Prescriptive Theory

5. Cognitive Integration

Conceptual integration

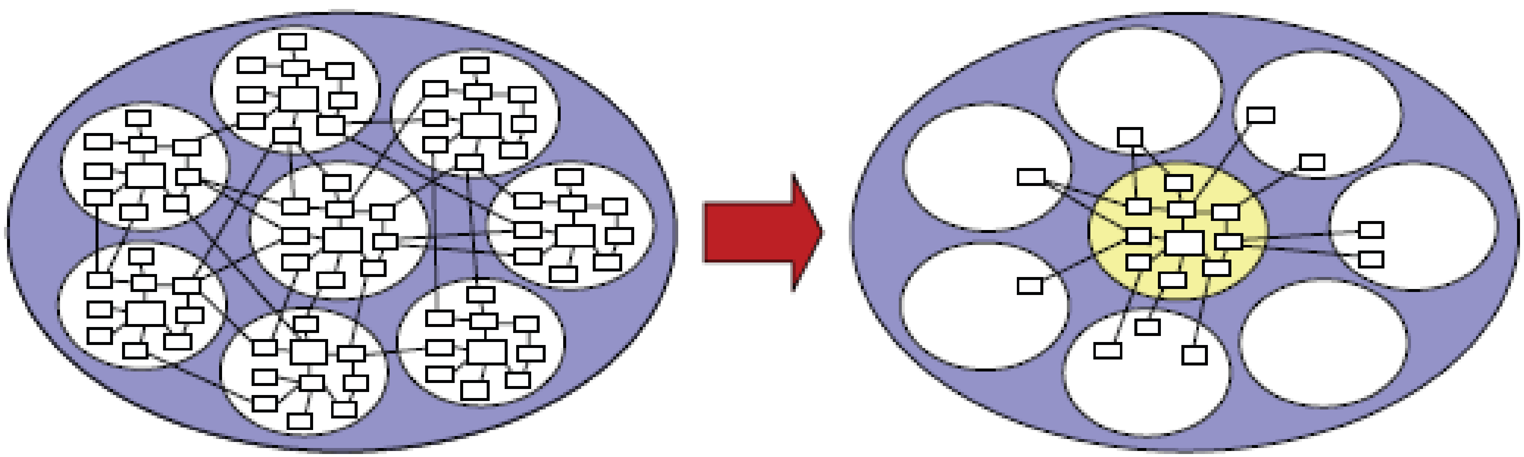


Figure 26. Contextualisation: each diagram should include its surrounding context to show how it fits into the system as a whole

Prescriptive Theory

5. Cognitive Integration

Perceptual integration

- Orientation
- Route choice
- Route monitoring
- Destination recognition

Prescriptive Theory

6. Visual Expressiveness

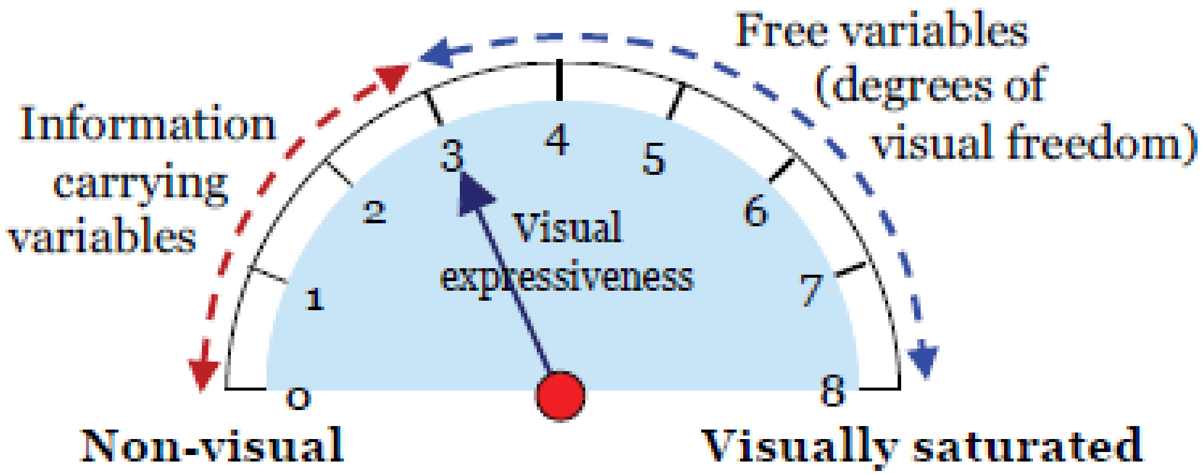


Figure 27. Visual Expressiveness

Prescriptive Theory

6. Visual Expressiveness

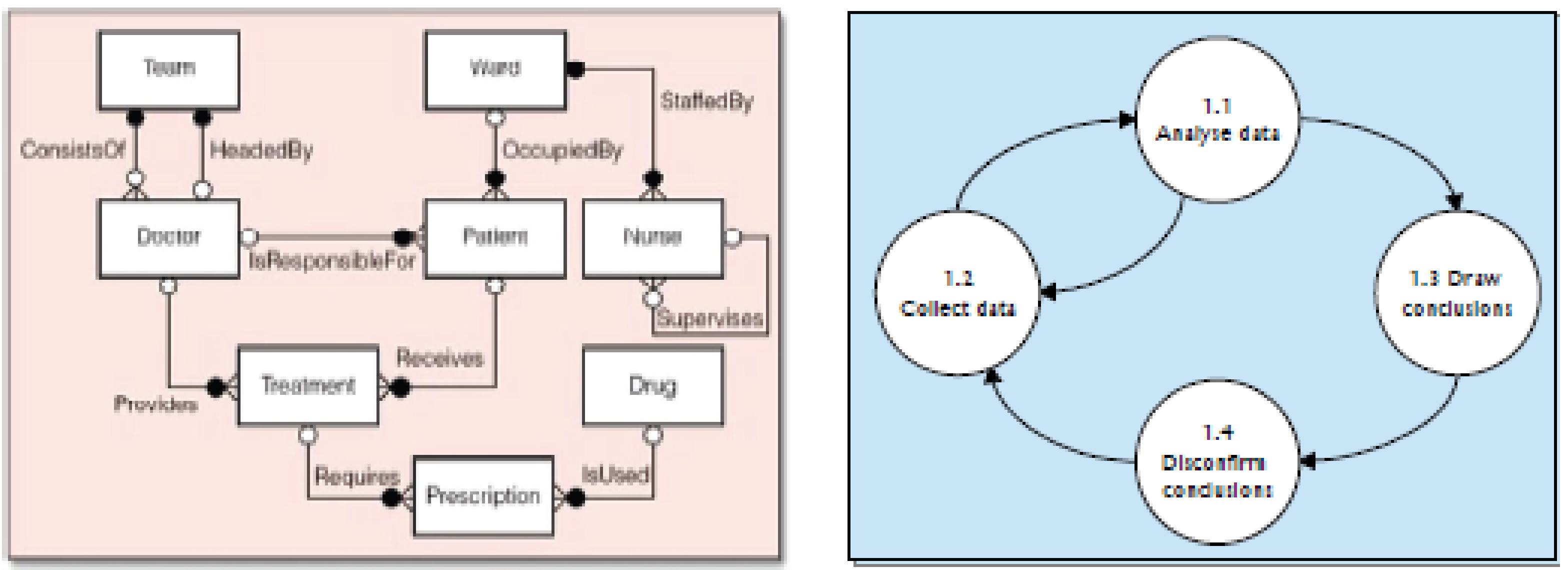
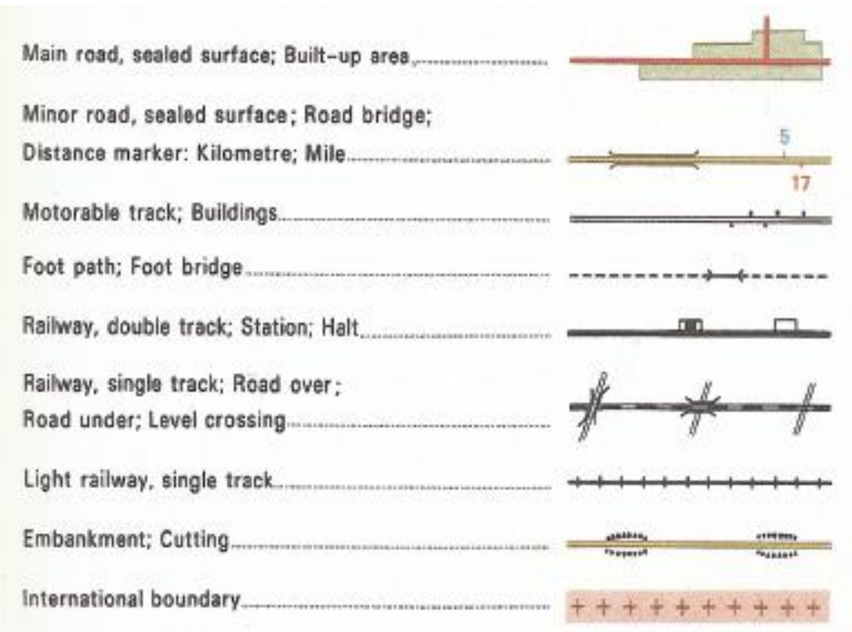
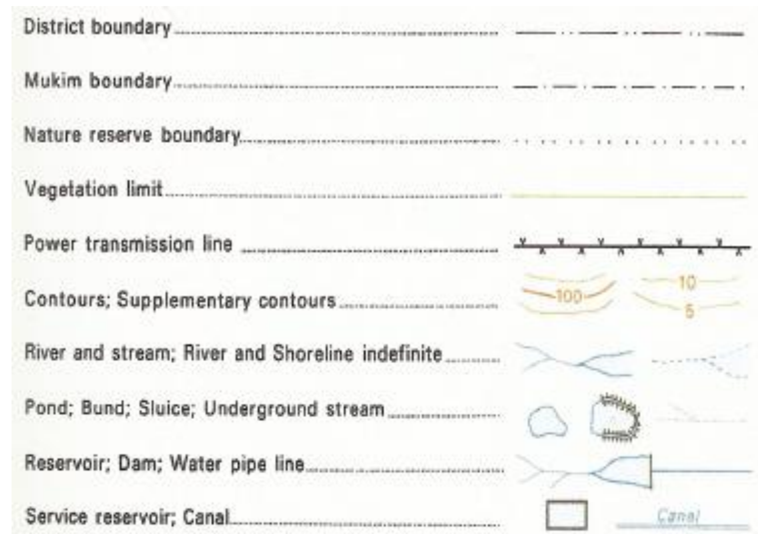


Figure 28. Visual Monosyllabism: ER diagrams and DFDs use only a single visual variable to encode information (shape).

Prescriptive Theory

6. Visual Expressiveness





Prescriptive Theory

6. Visual Expressiveness

Table 2. Different visual variables have different capabilities for encoding information: Power = highest level of measurement that can be encoded; Capacity = number of perceptible steps

Variable	Power	Capacity
Horizontal position (x)	Interval	10-15
Vertical position (y)	Interval	10-15
Size	Interval	20
Brightness	Ordinal	6-7
Colour	Nominal	7-10
Texture	Nominal	2-5
Shape	Nominal	Unlimited
Orientation	Nominal	4

Prescriptive Theory

7. Dual Coding

Perceptual Discriminability and Visual Expressiveness say no to text

However when we use both, information is encoded in separate systems in working memory and referential connections are strengthened

Prescriptive Theory

7. Dual Coding

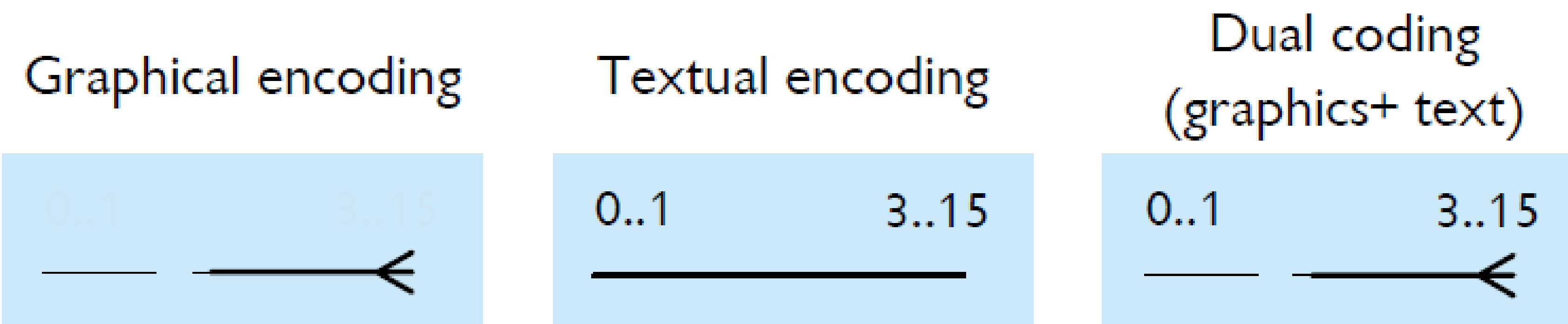


Figure 32. Dual Coding: the Best of Both Worlds?

Prescriptive Theory

8. Graphic Economy

Everything does not have to be in a diagram!

More is not necessarily better.

Prescriptive Theory

9. Cognitive fit

- Know thy audience
  - Novices have trouble recalling multiple symbols
  - Novices have trouble discriminating between symbols
  - Novices are affected by complexity
- Know thy medium
  - Whiteboard? Paper? Computer program?

Prescriptive Theory

10. Combining principles

	Semiotic Clarity	Perceptual Discriminability	Semantic Transparency	Complexity Management	Cognitive Integration	Visual Expressiveness	Dual Coding	Graphic Economy	Cognitive Fit
Semiotic Clarity								±	
Perceptual Discriminability						+			+
Semantic Transparency		+							±
Complexity Management								–	+
Cognitive Integration	–			+				–	
Visual Expressiveness		+						+	±
Dual Coding									+
Graphic Economy		+		+		–			+
Cognitive Fit									

Figure 36. Interactions between principles: + indicates a positive effect, – indicates a negative effect, ± indicates a positive or negative effect depending on the situation

Theory for Visual Notation Design

- Conclusions and significance

- Visual syntax has been undervalued or ignored

- Key points:
  - Design goal
  - Descriptive theory
  - Prescriptive theory