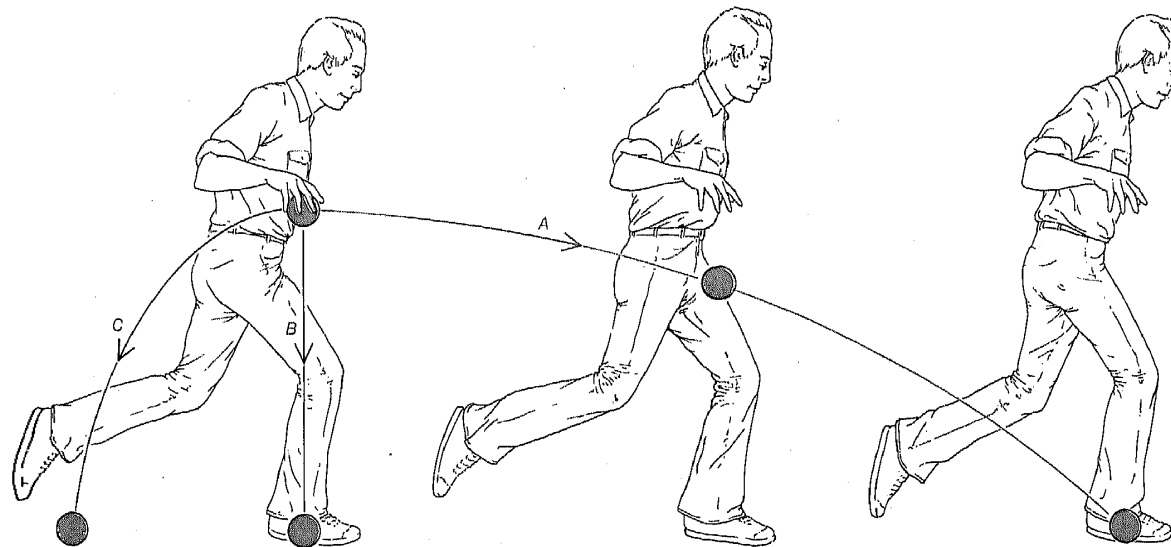


The “Physics” of Notations



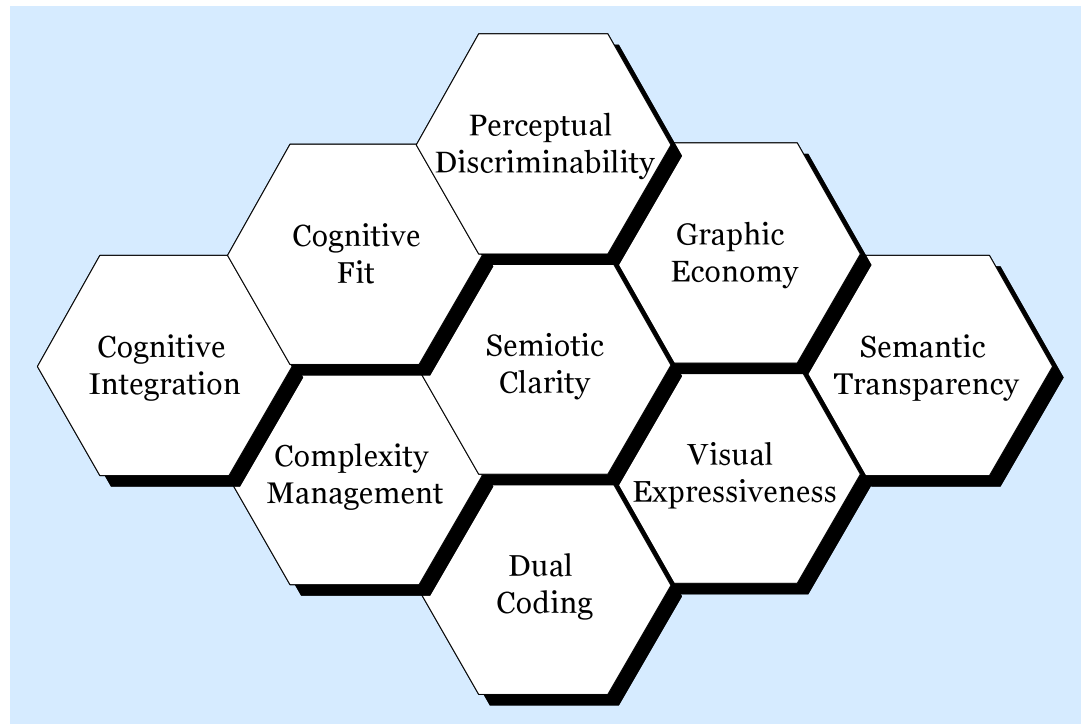
Improving the Usability and Communicability
of Visual Notations in Requirements
Engineering



University of Twente

The Physics of Notations: A Theory for Visual Notation Design

Scientific basis for
evaluating,
comparing,
improving, and
designing visual
notations



Source: Moody, D.L. (2009): The “Physics” of Notations: Towards a Scientific Basis for Constructing Visual Notations in Software Engineering. *IEEE Transactions on Software Engineering*, December.

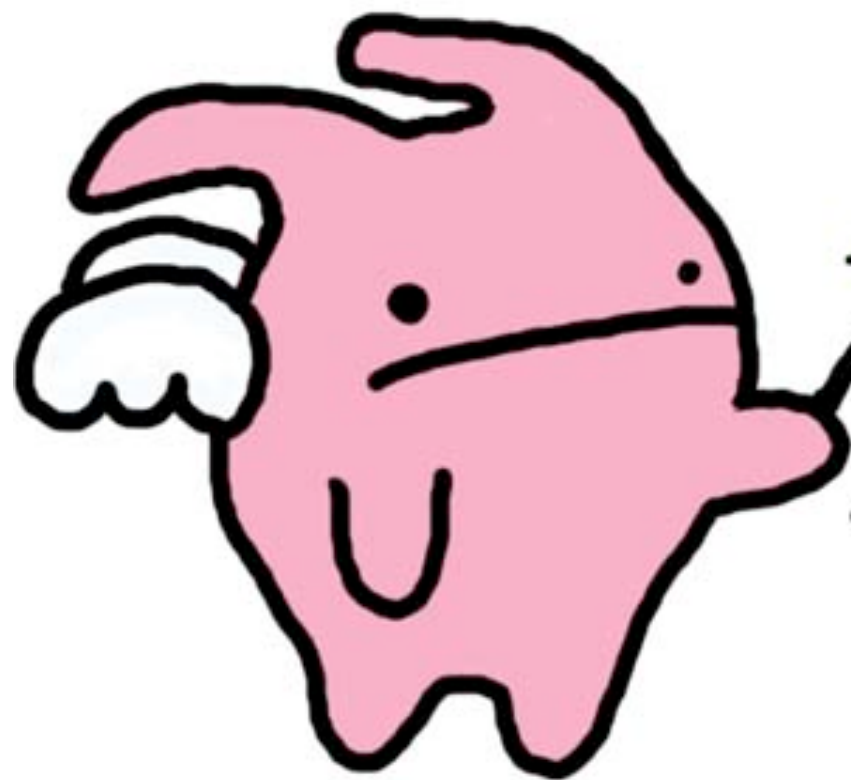
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Max Planck – brilliant
physicist, lousy pick-up
artist

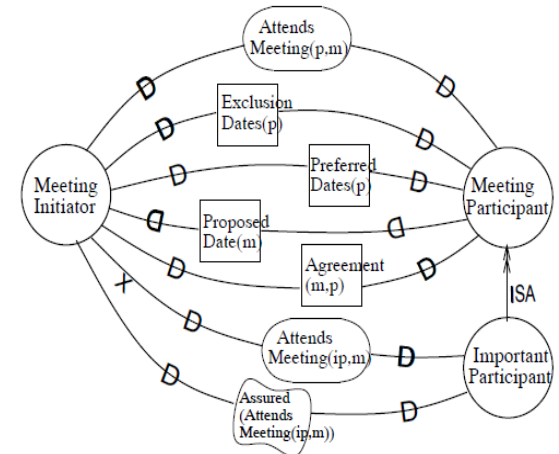
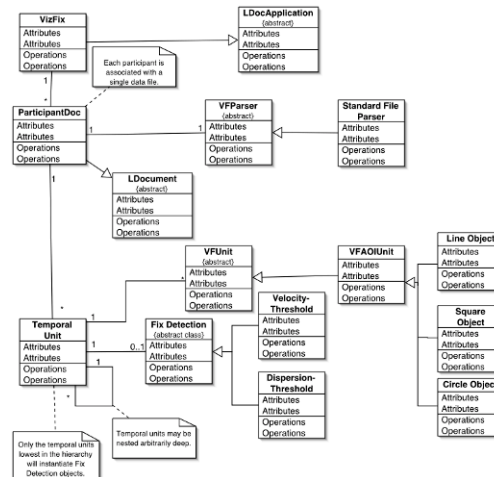
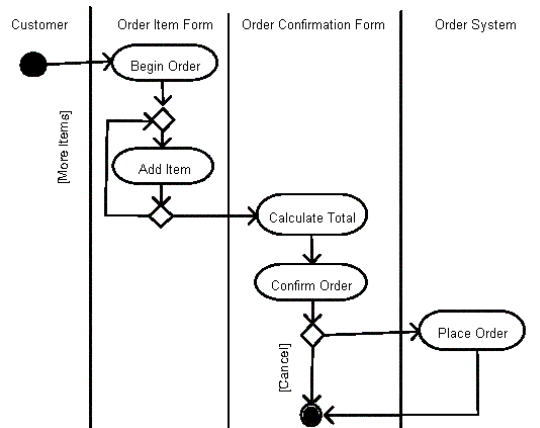
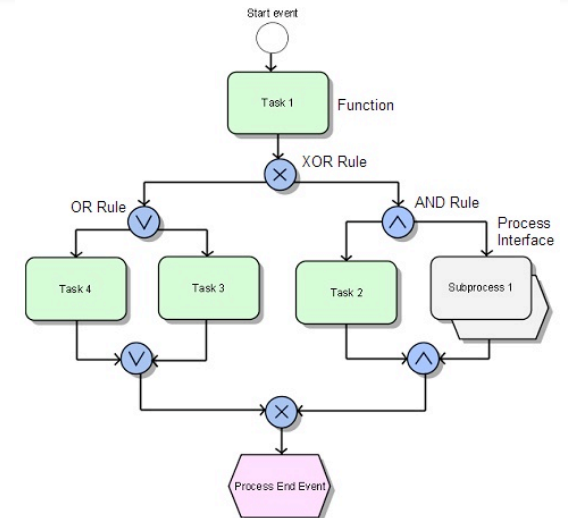
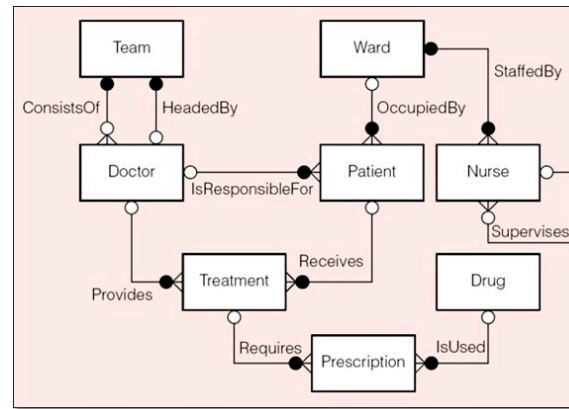
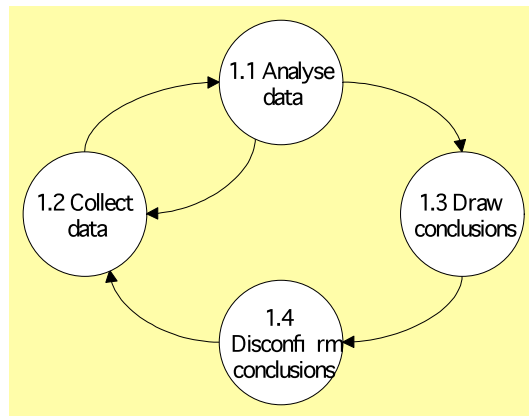
The “Physics” of Notations: A Scientific Approach to Designing Visual Notations

1. The Nature of Visual Notations
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6. Conclusion

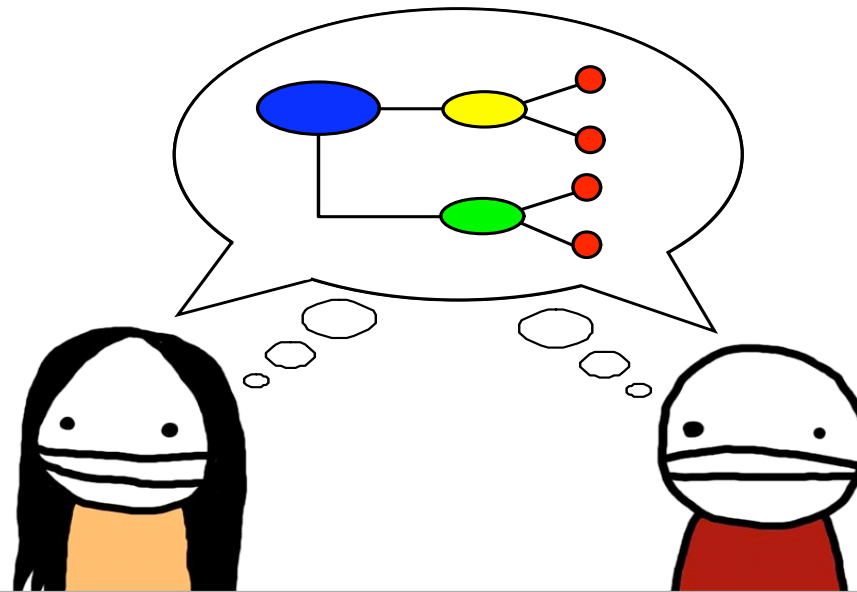


i promise to grant
you three wishes
if you promise to
just shut the hell up.

Visual notations are pervasively used in requirements engineering



The Dependent Variable: What Makes a “Good” Visual Notation?



Cognitive Effectiveness = speed, ease and accuracy with which a representation can be processed by the human mind

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Design of SE visual notations is ad hoc and unscientific

- ★ A job for amateurs
- ★ A low priority task
- ★ Lack of design rationale
- ★ Lack of explicit principles



Justification of design choices: design rationale

“Very little is documented about why particular graphical conventions are used. Texts generally state what a particular symbol means without giving any rationale for particular symbols or saying why the symbol chosen is to be preferred to those already available. The reasons for choosing particular graphical conventions are generally shrouded in mystery.”

Source: Hitchman, S. “The Details of Conceptual Modelling Notations are Important - A Comparison of Relationship Normative Language”, *Communications of the AIS* (9:10) 2002.

“Show and tell”

“In this section, we introduce a diagrammatic technique for exhibiting entities and relationships: the entity-relationship diagram. Figure 10 illustrates the relationship set PROJECT-WORKER and the entity sets EMPLOYEE and PROJECT using this diagrammatic technique. Each entity set is represented by a rectangular box, and each relationship set is represented by a diamond-shaped box.”

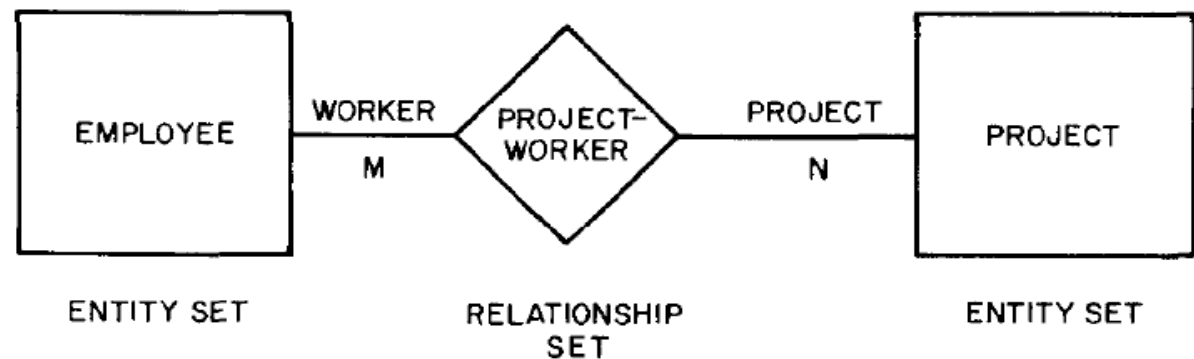
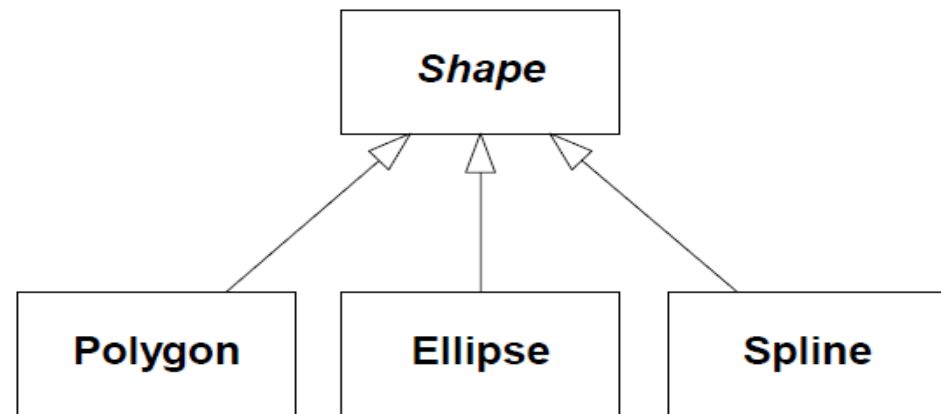


Fig. 10. A simple entity-relationship diagram

Source: Chen, P.P. (1976): The Entity Relationship Model: Towards An Integrated View Of Data. *ACM Transactions on Database Systems*, 1(1)

“Show and tell”

“A generalization is shown as a line with a hollow triangle as an arrowhead between the symbols representing the involved classifiers. The arrowhead points to the symbol representing the general classifier.”



Source: OMG (2005): *Unified Modeling Language Version 2.0: Superstructure*. Object Management Group (OMG).

“Show only”

“Figure 2 shows an SD model of the meeting scheduling setting with a computer-based meeting scheduler.”

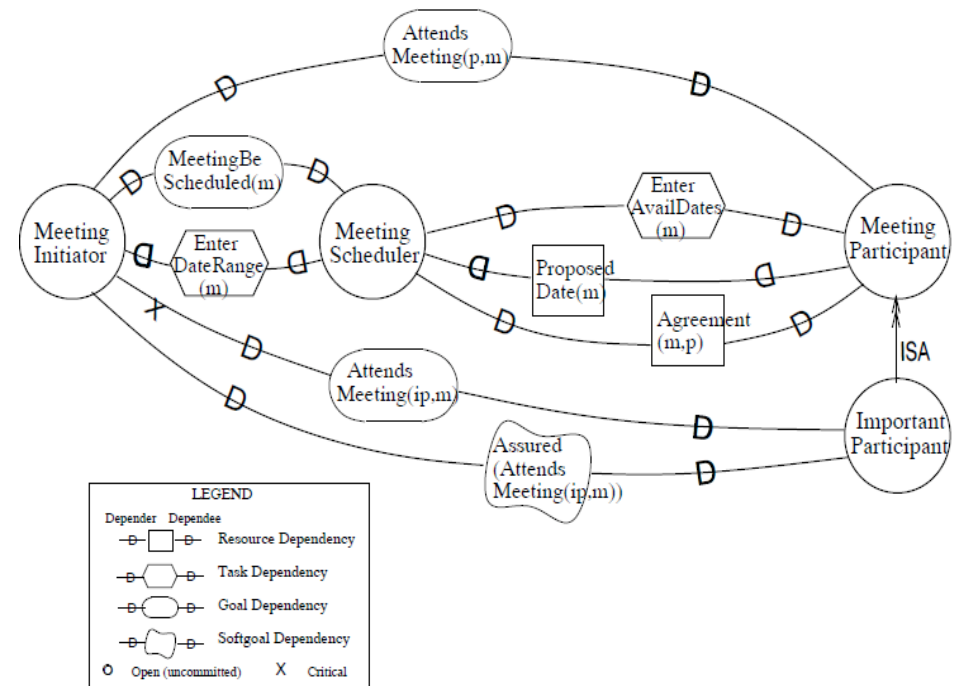
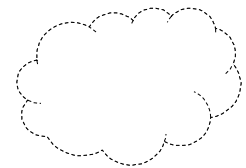
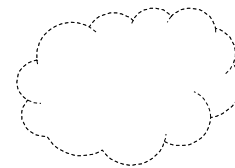
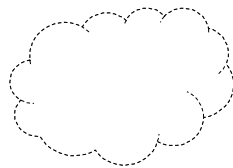
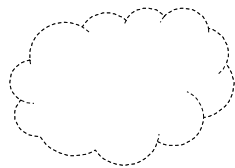


Figure 2: Strategic Dependency model for meeting scheduling with computer-based scheduler

Source: Yu, E (1997): Towards Modelling and Reasoning Support for Early-Phase Requirements Engineering. *3rd IEEE International Conference on Requirements Engineering (RE'97)*.

Design rationale (as good as it gets)

“The selection of icons for any notation is a difficult task and not to be taken lightly. Indeed, icon design is largely an art not a science and requires a careful balance between expressiveness and simplicity. Our choice of the cloud icon suggests the boundaries of an abstraction, a concept that does not necessarily have plain or simple edges. The dashed lines indicate that clients generally only operate upon instances of a class, not the class itself.”



Source: Booch, G., Object-Oriented Analysis and Design with Applications (2nd edition). 1994, Redwood City, California, USA: Benjamin Cummings Publishing.

The real inspiration...

“How sweet to be a Cloud
Floating in the Blue!”
It makes him very proud
To be a little cloud.



Source: Milne, A.A. (1926): *Winnie-the-Pooh*. London, England: Methuen & Co. Ltd.

Unselfconscious design culture

- ★ Instinct, imitation, tradition
- ★ Inability to explain designs
- ★ Lack of variety



Source: Alexander, C.W., *Notes On The Synthesis Of Form*. 1970, Boston, USA: Harvard University Press. 224.

There must be another way...



“Here is Winnie-the-Pooh coming downstairs, bump, bump, bump on the back of his head. It is, as far as he knows, the only way of coming downstairs, but sometimes he feels that there really is another way, if only he could stop bumping for a moment to think of it...”

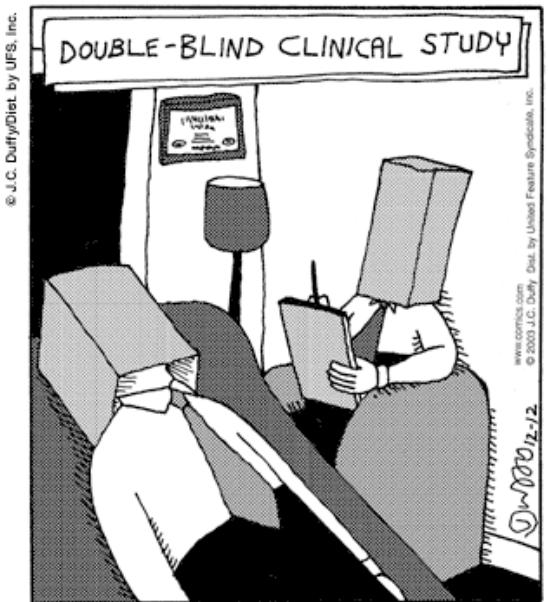
Evidence-based Visual Notation Design

Evidence-based medicine (EBM)

- ★ Decisions about patient care made based on the best available research evidence

Evidence-based visual notation design

- ★ Visual representation decisions based on scientific evidence on cognitive effectiveness



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Cognitive Dimensions of Notations (CDs)

“Broad-brush” analysis of **cognitive artifacts**

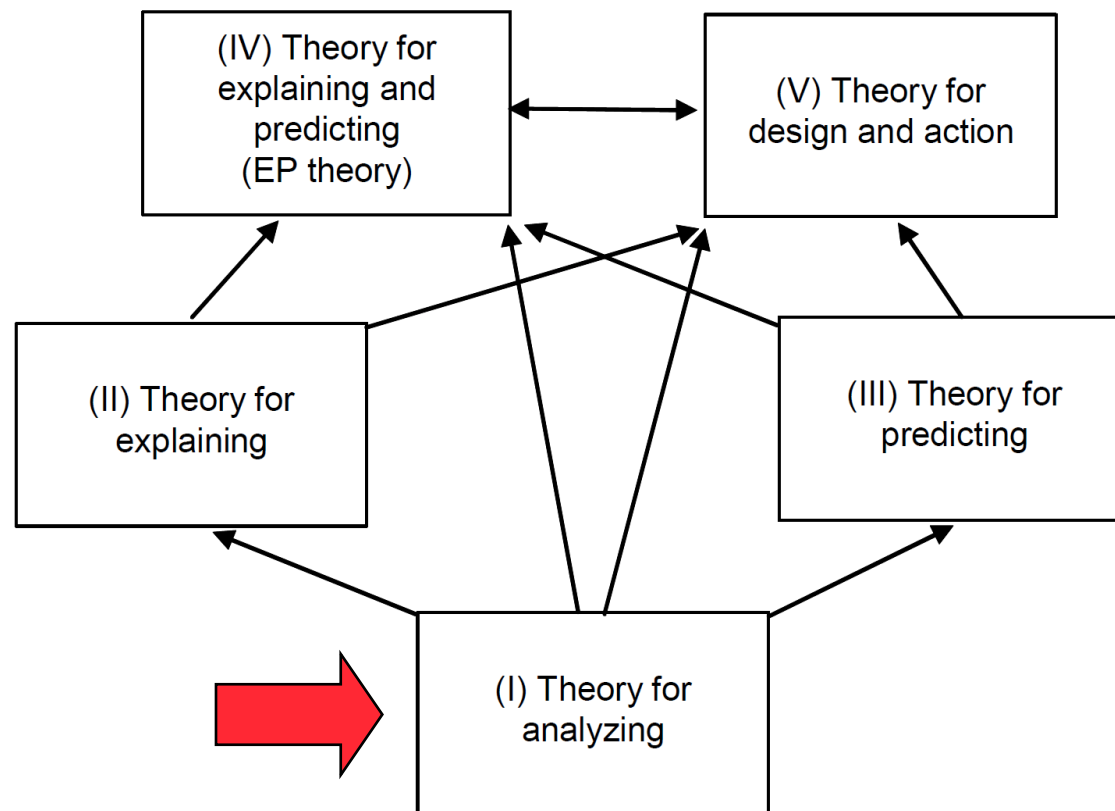
Abstraction gradient	Closeness of Mapping	Consistency	Diffuseness (Terseness)	
Error-proneness	Hard mental operations	Hidden dependencies	Premature commitment	Progressive evaluation
Role-expressiveness	Secondary notation	Viscosity	Visibility and juxtaposability	

Source: Green, T. R. G. and M. Petre (1996). "Usability Analysis of Visual Programming Environments: A 'Cognitive Dimensions' framework." *Journal of Visual Languages and Computing* 7: 131-174.

Cognitive Dimensions of Notations (CDs)

- ★ Not developed for visual notations
- ★ Lack of precision
- ★ Lack of theoretical and empirical grounding
- ★ No testable propositions (\Rightarrow unfalsifiable)
- ★ Non-evaluative (Gulf of Evaluation)
- ★ Non-prescriptive (Gulf of Execution)

Theory Types

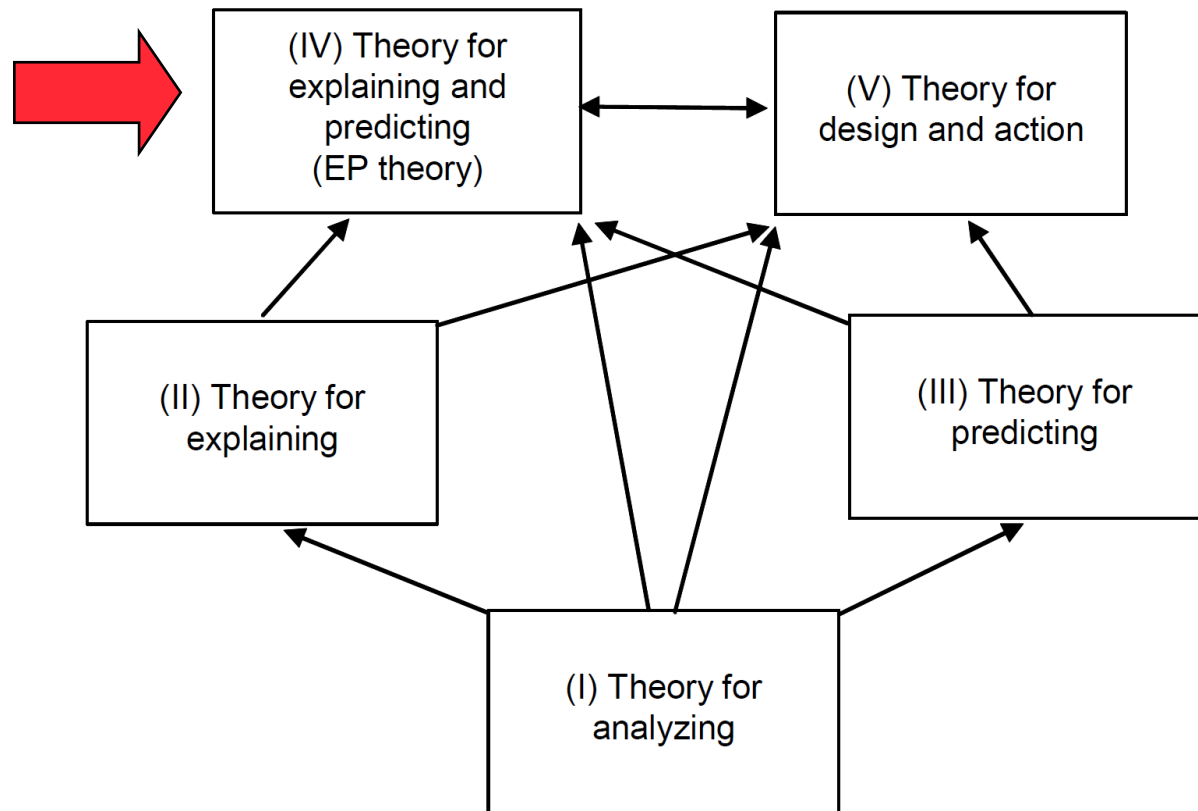


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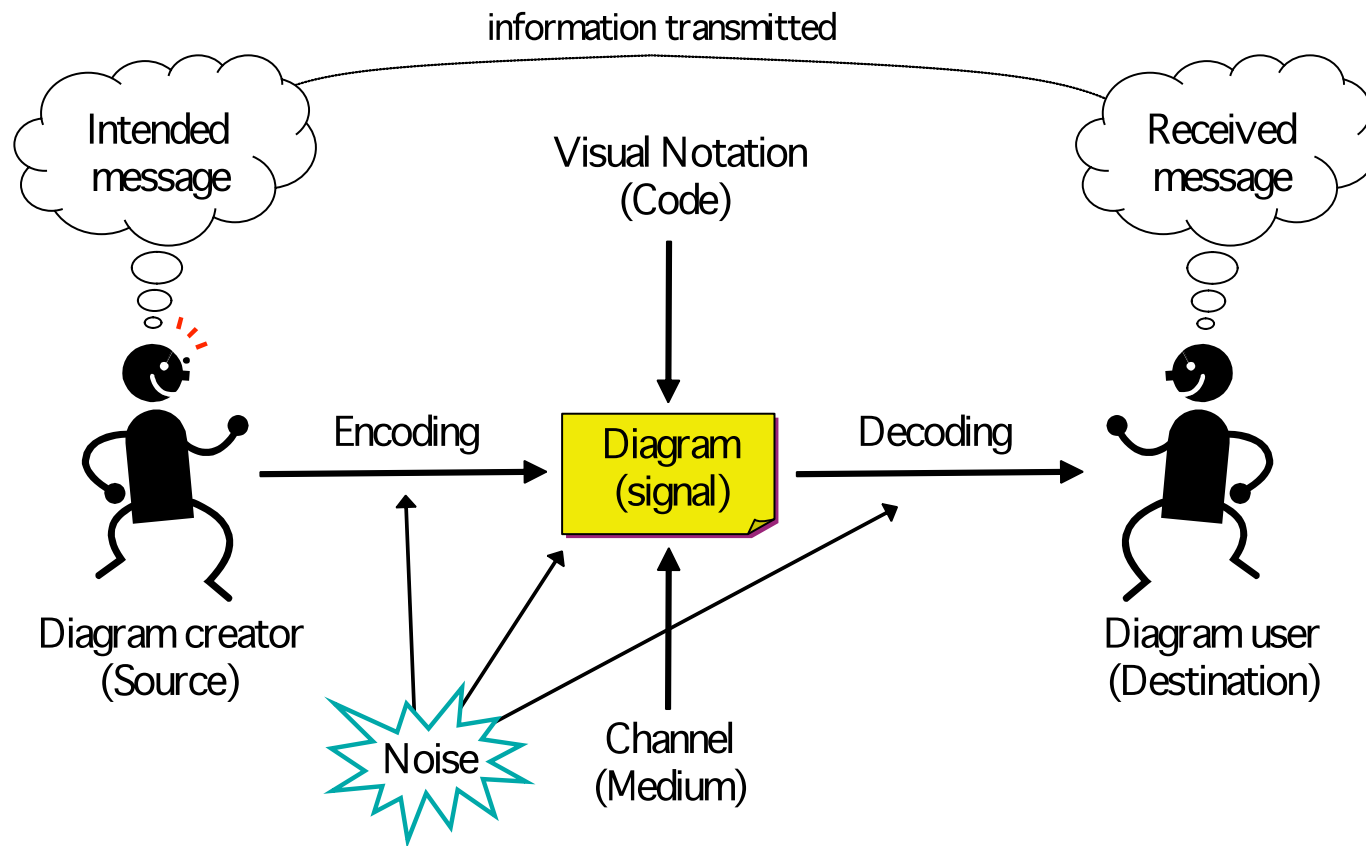
1. The Nature of Visual Notations
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Theory Types

How visual
notations
communicate

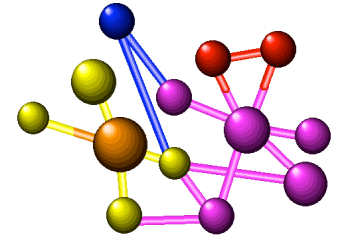


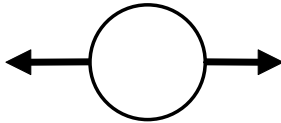
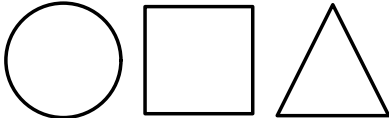
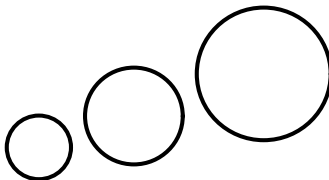
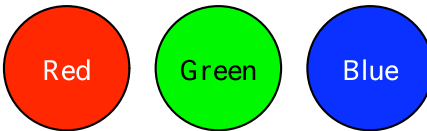
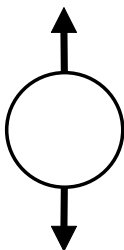
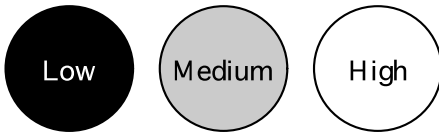
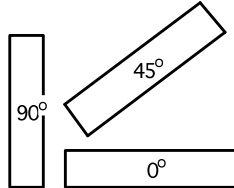
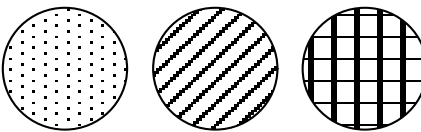
Descriptive Theory: How Visual Notations Communicate



Source: Shannon, C.E. and Weaver, W. *The Mathematical Theory of Communication*. University of Illinois Press, Urbana, Illinois, USA, 1963.

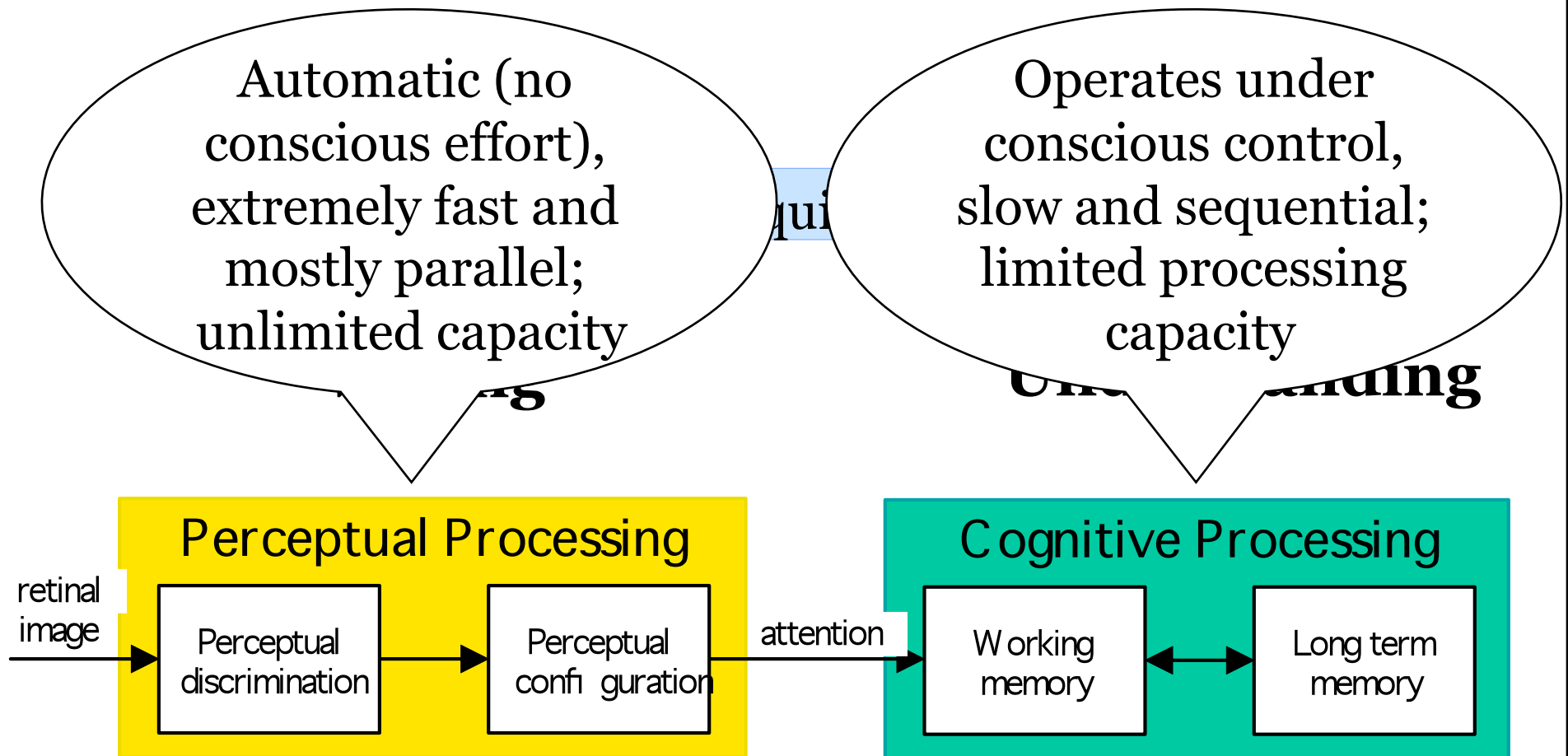
The Design Space (encoding side): The Symbol System of Graphics



PLANAR VARIABLES	RETINAL VARIABLES		
Horizontal Position 	Shape 	Size 	Colour 
Vertical Position 	Brightness 	Orientation 	Texture 

Source: Bertin, J. *Semiology of Graphics: Diagrams, Networks, Maps*.
University of Wisconsin Press, Madison, Wisconsin, USA, 1983.

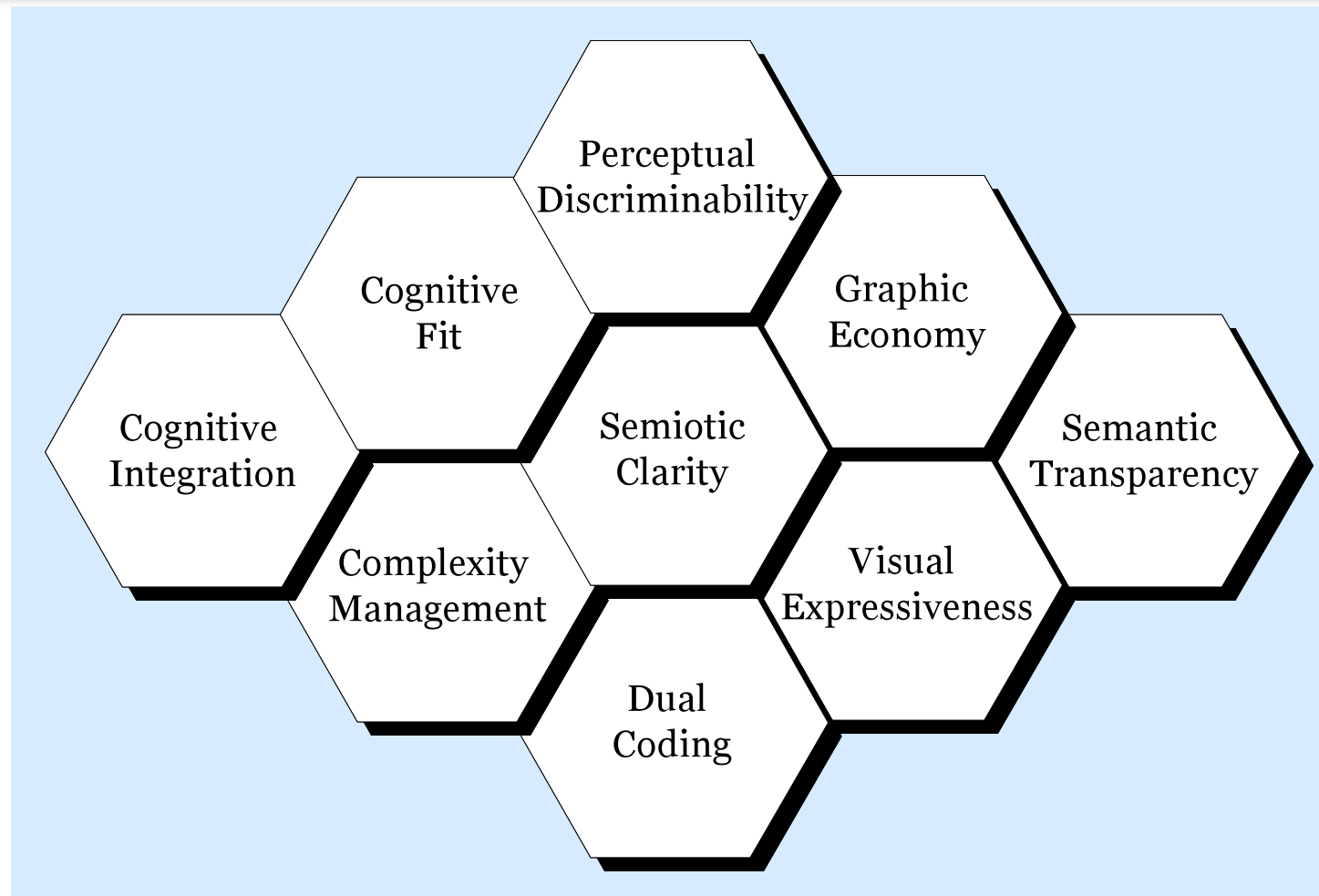
The Solution Space (decoding side): Human Graphical Information Processing



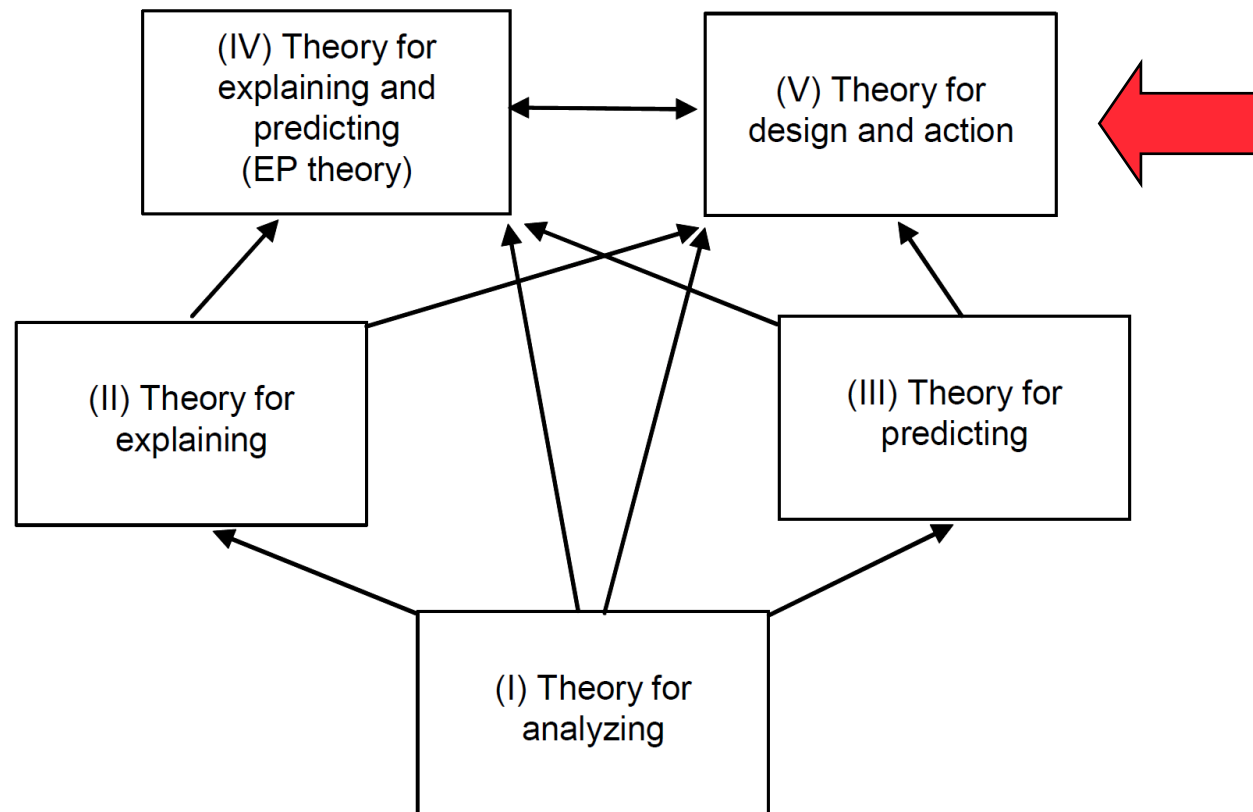
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Prescriptive Theory: Principles for Cognitively Effective Visual Notations



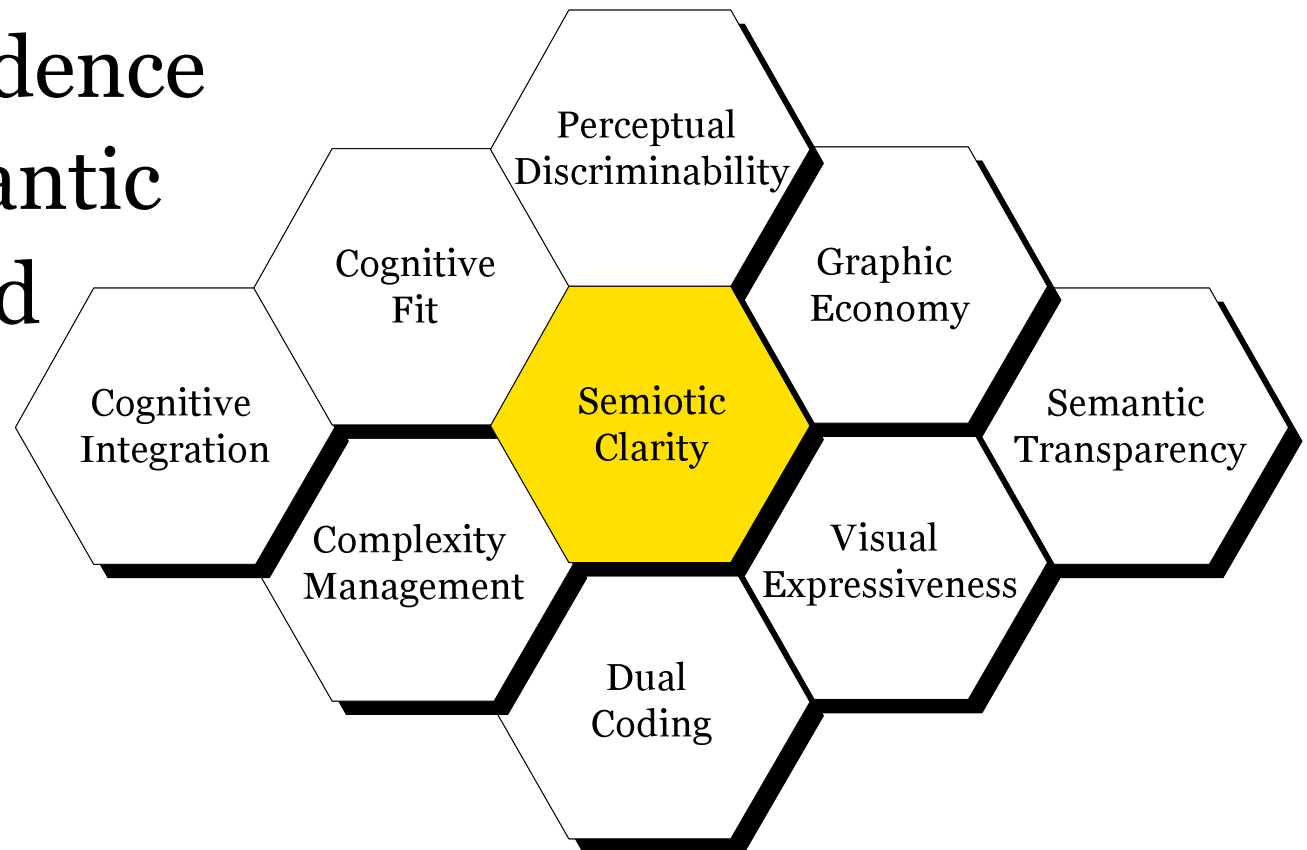
Theory Types



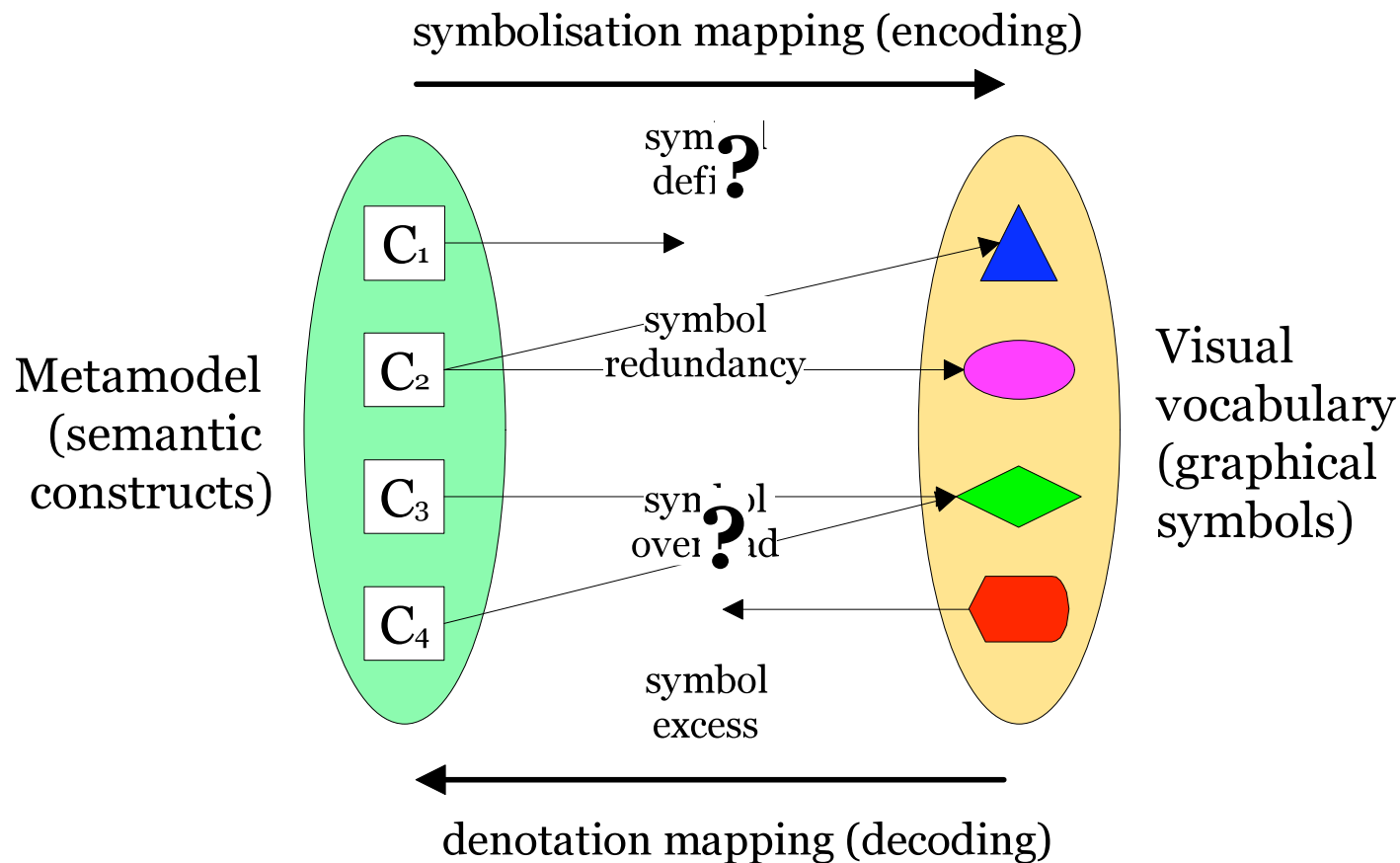
Principles
for designing
visual
notations

1. Principle of Semiotic Clarity

There should be a 1:1 correspondence between semantic constructs and graphical symbols

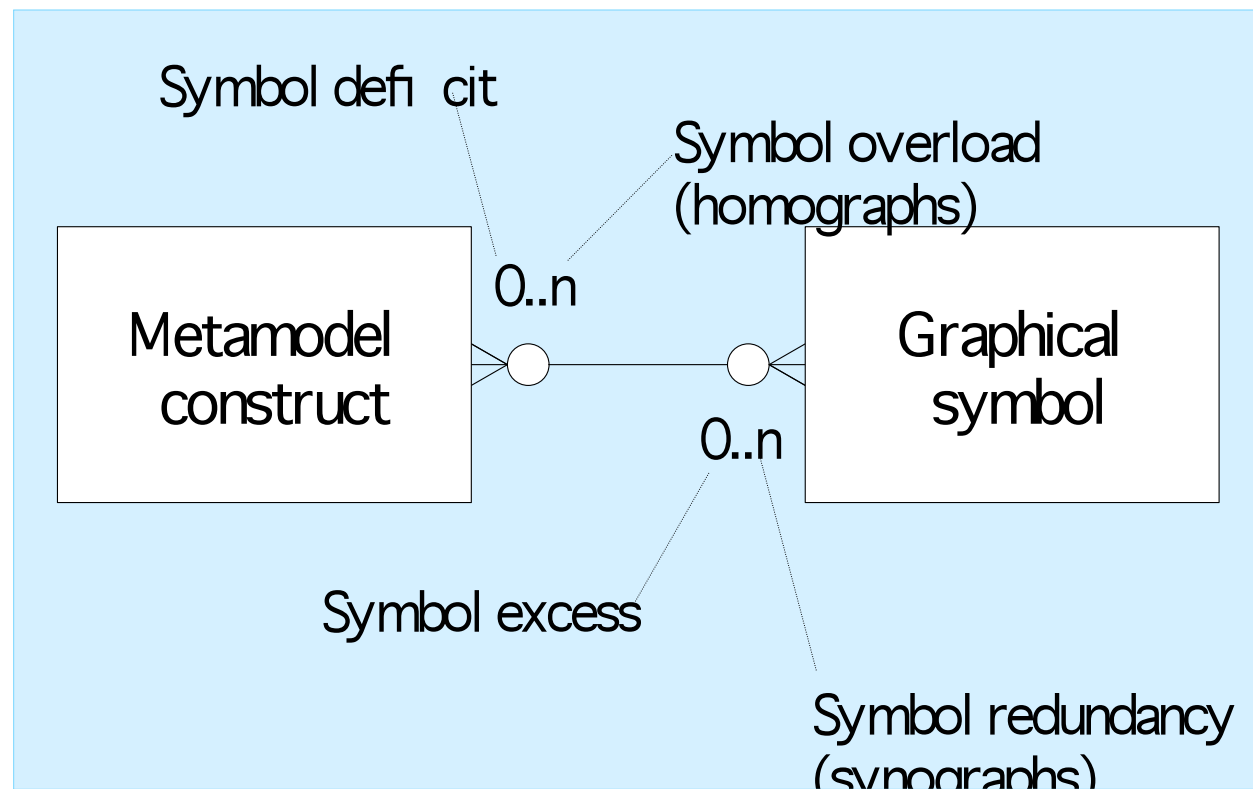


1. Principle of Semiotic Clarity



Source: Goodman, N. *Languages of Art: An Approach to a Theory of Symbols*. Bobbs-Merrill Co, Indianapolis, 1968.

Principle of Semiotic Clarity

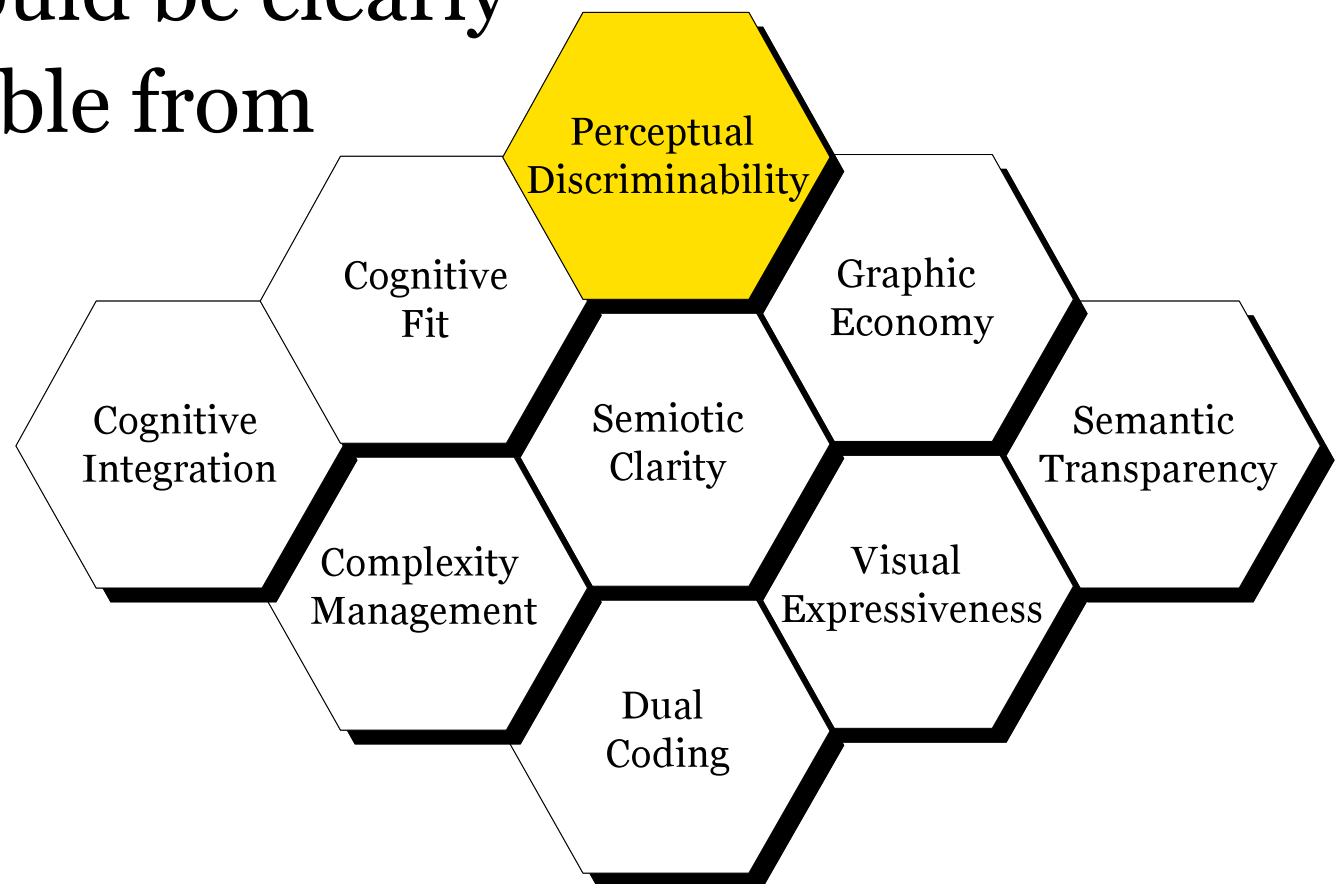


Semiotic Clarity Analysis Summary (UML)

Diagram Type	Constructs	Symbols	Symbol redundancy	Symbol overload	Symbol excess	Symbol definition	Contextual differentiation	Textual differentiation
Classes	55	46	15	25	3	29	7	19
Components	4	7	4	4	0	0	3	3
Composite	14	15	3	8	1	7	5	6
Deployments	12	13	4	11	0	3	4	6
Activities	52	33	10	14	1	14	7	4
Interactions	28	16	0	4	0	8	4	4
State Machines	16	21	3	7	2	4	2	6
Use Cases	6	10	3	1	1	0	1	1
Average			26%	46%	5%	35%	20%	30%

2. Principle of Perceptual Discriminability

Symbols should be clearly distinguishable from one another



Principle of Perceptual Discriminability

- ★ Principle of difference (semiotics): a sign signifies by virtue of its difference from other signs
- ★ Psychophysics: difference thresholds (just noticeable differences)

Sources: De Saussure, F. (1983). *Course in General Linguistics* (R. Harris, Translator). La Salle, Illinois: Open Court Publishing Company.

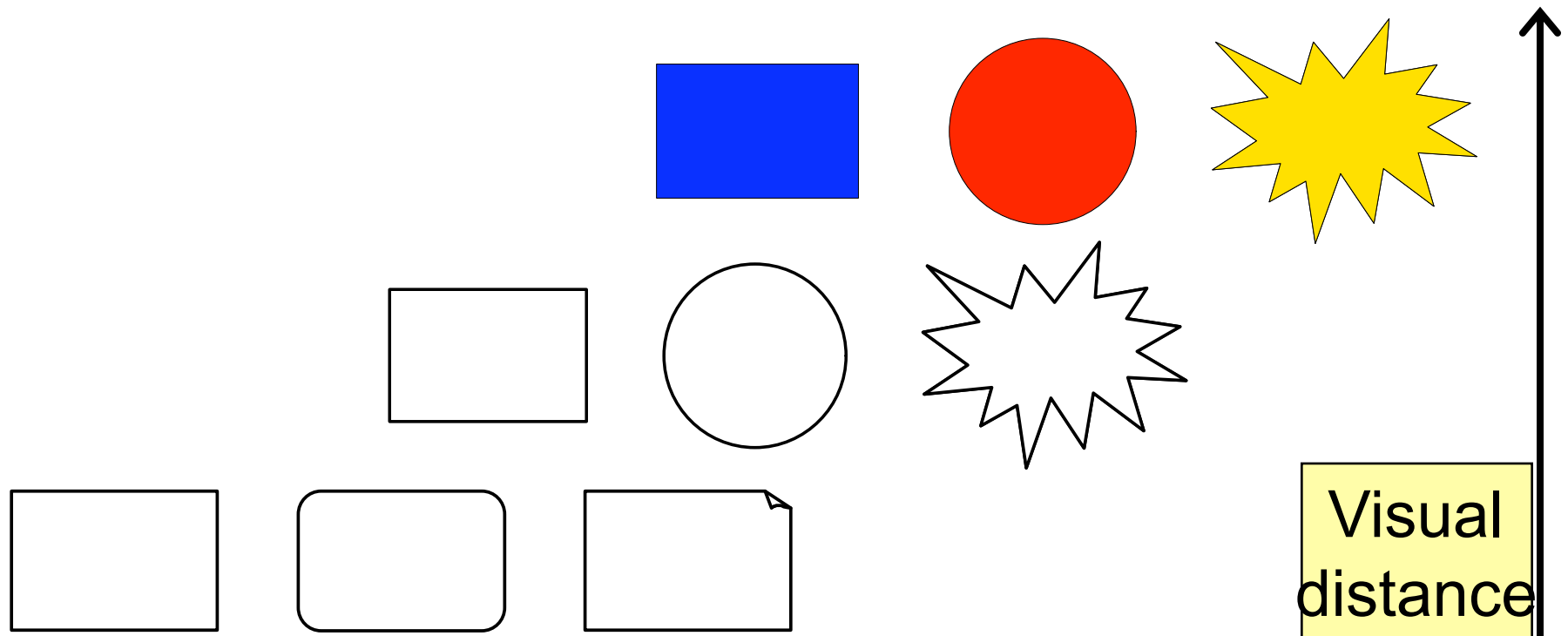
Stevens, S. S. (1975). *Psychophysics*. New York: John Wiley & Sons.

Perceptual discriminability in action

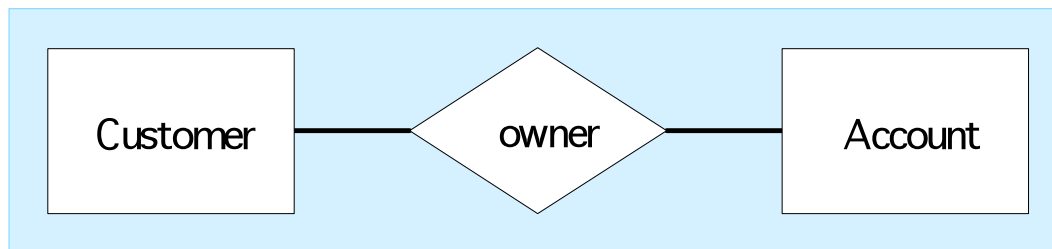
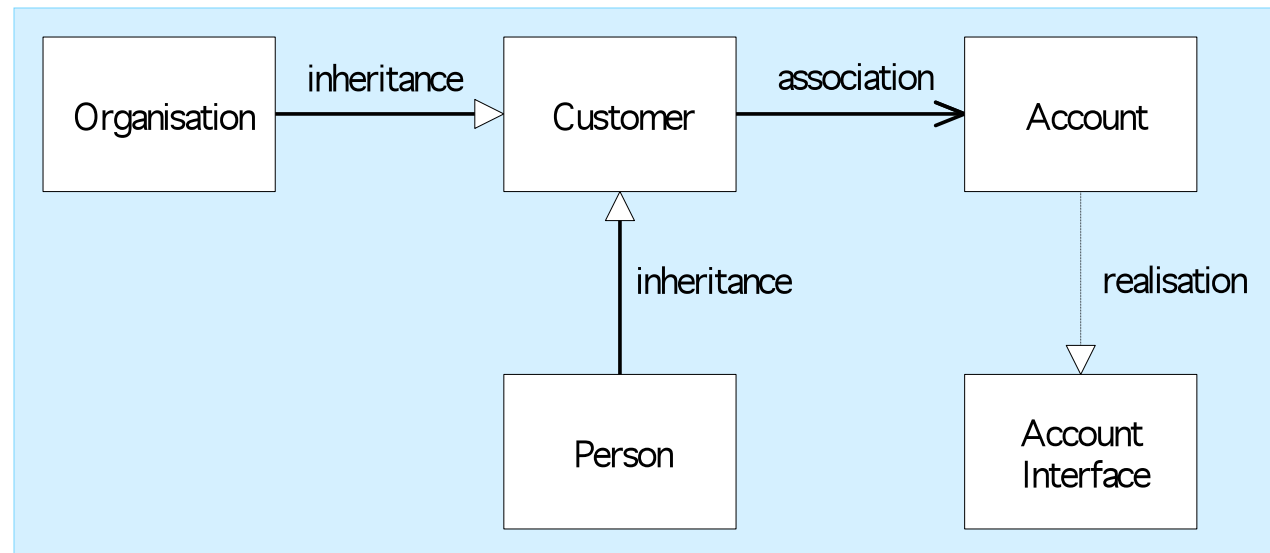


Visual Distance

Number of visual variables on which symbols differ + size of differences

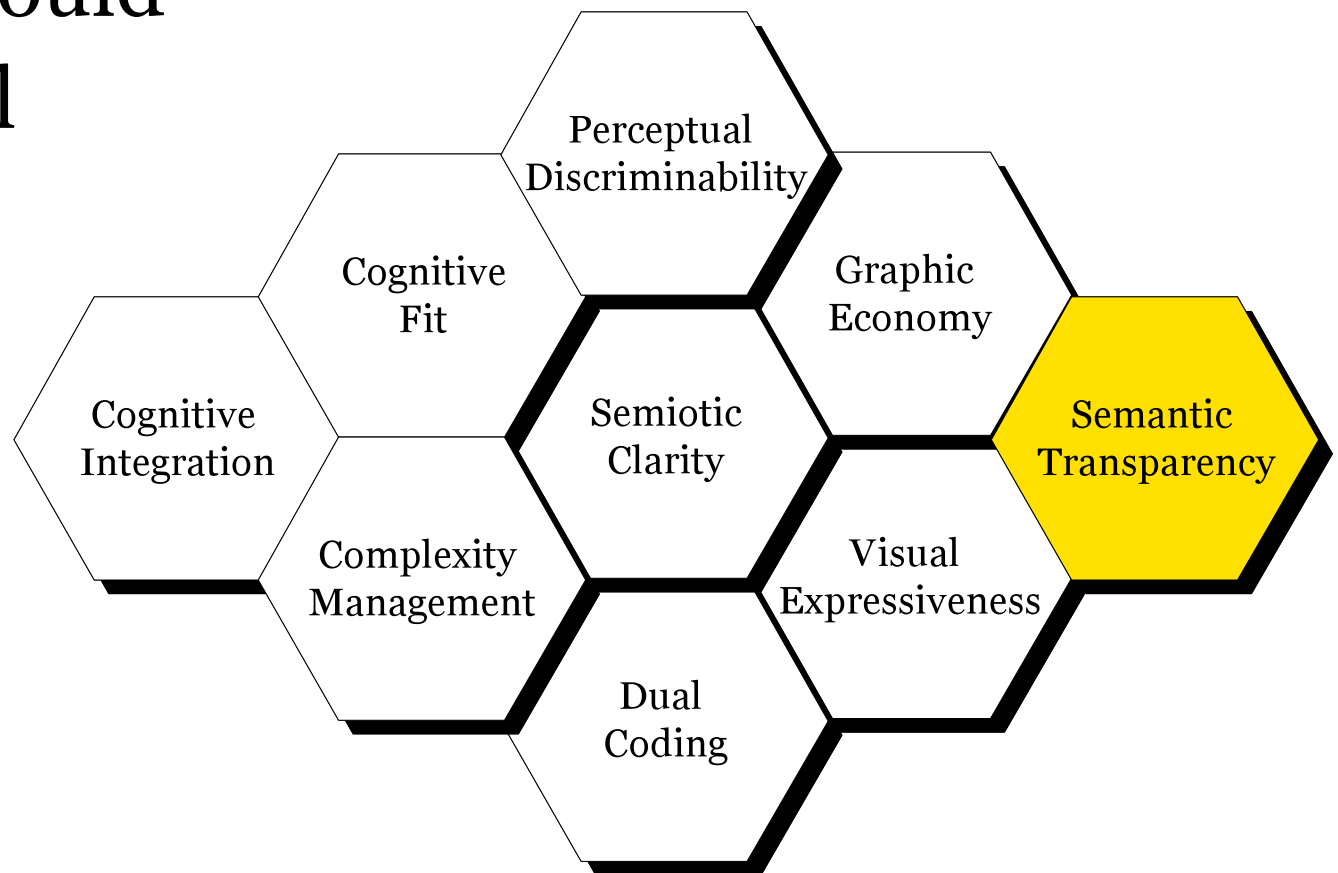


Discriminability of SE visual notations

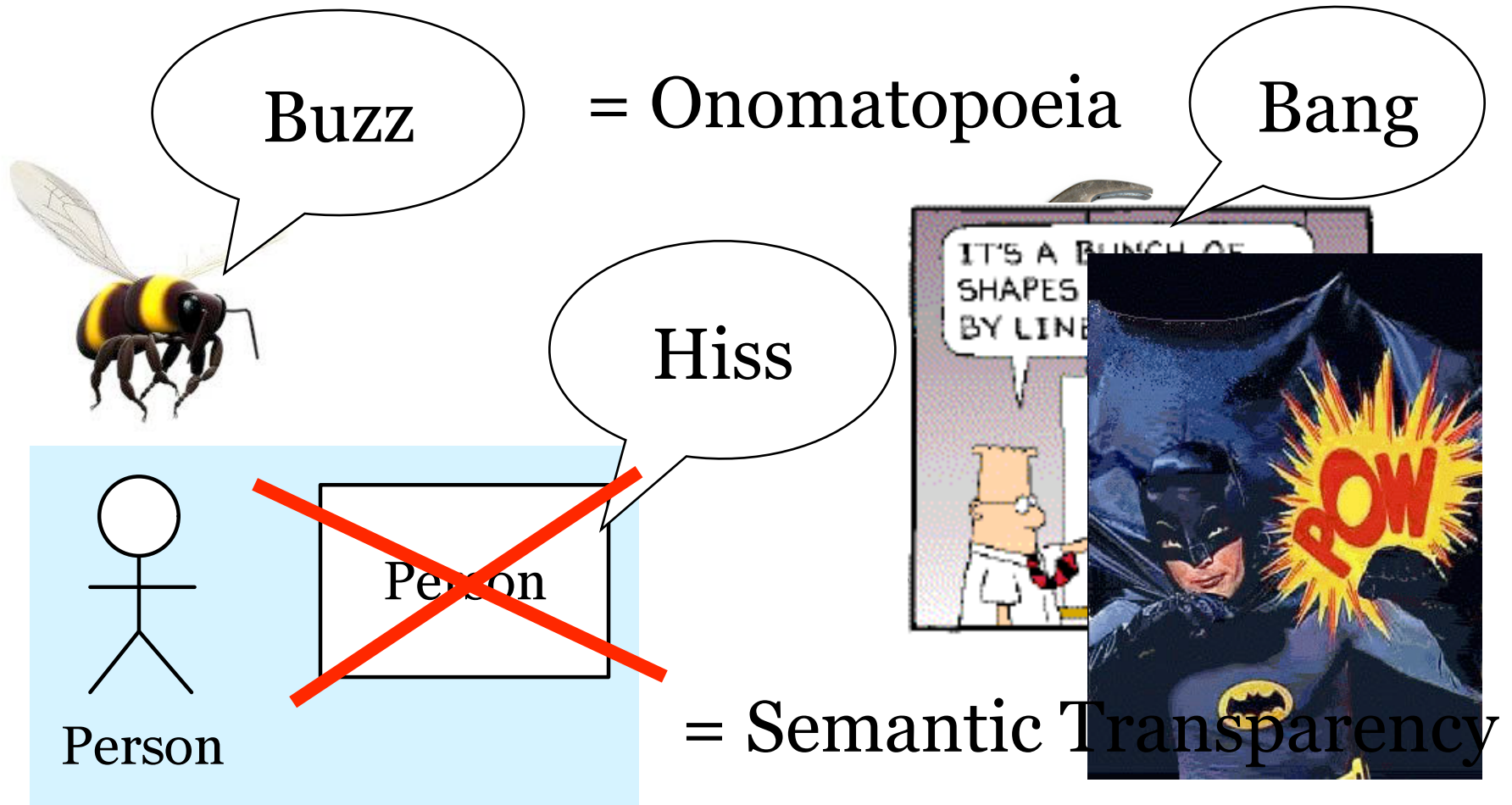


3. Principle of Semantic Transparency

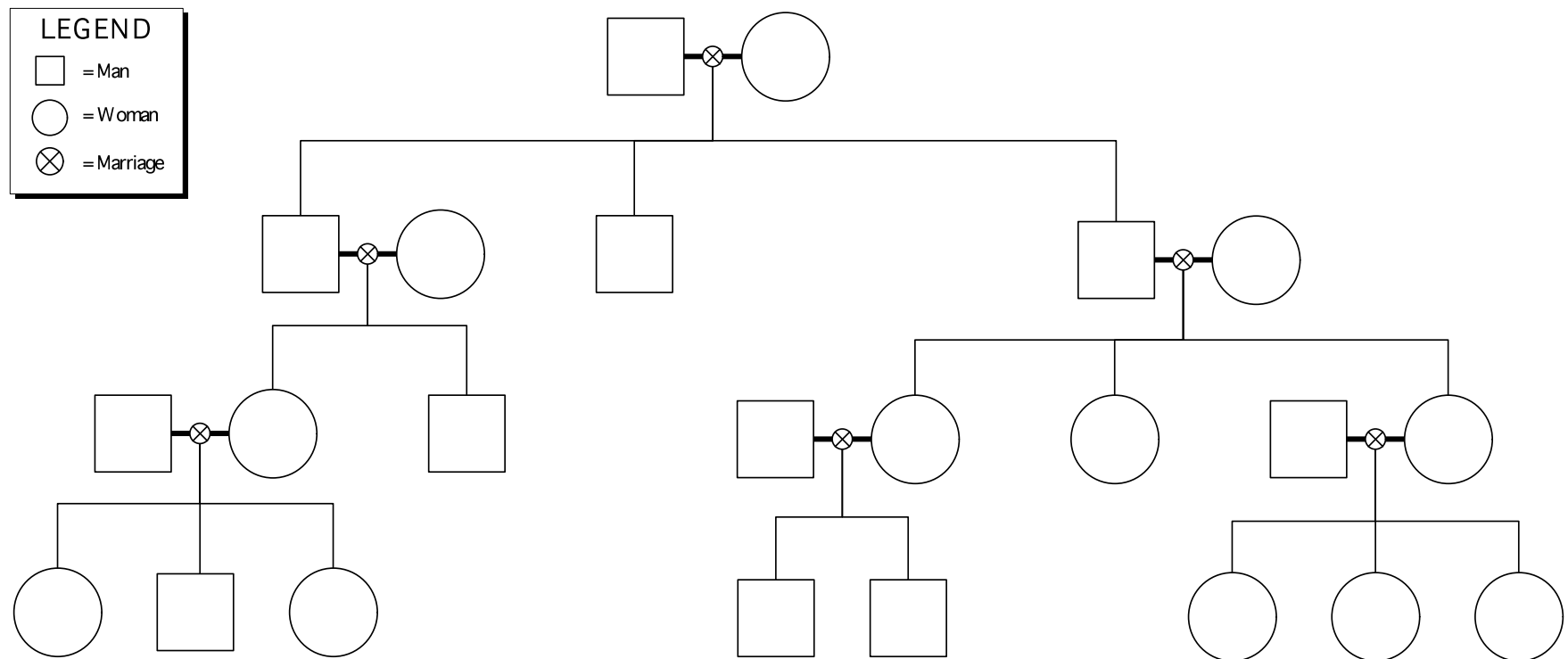
Notations should use graphical symbols that suggest their meaning



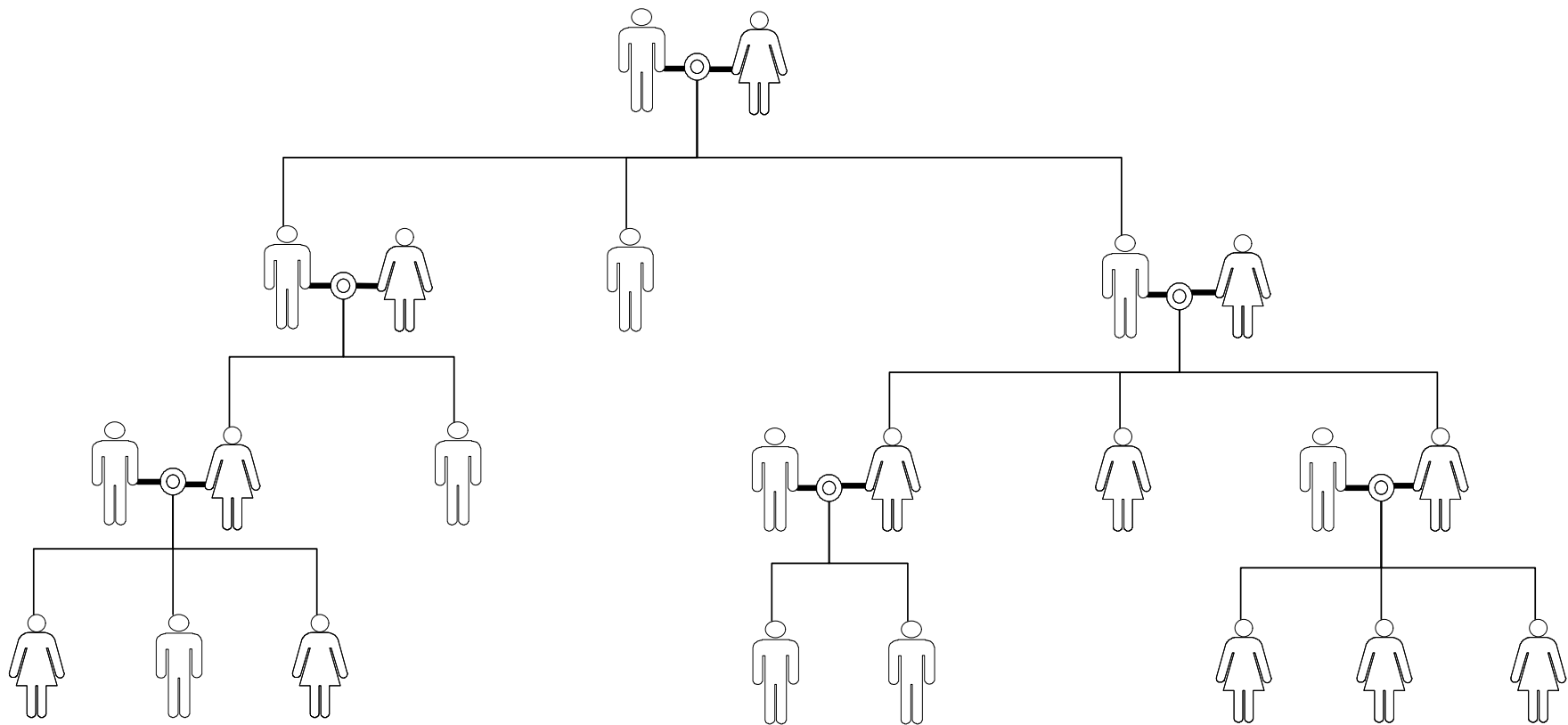
Semantic Transparency



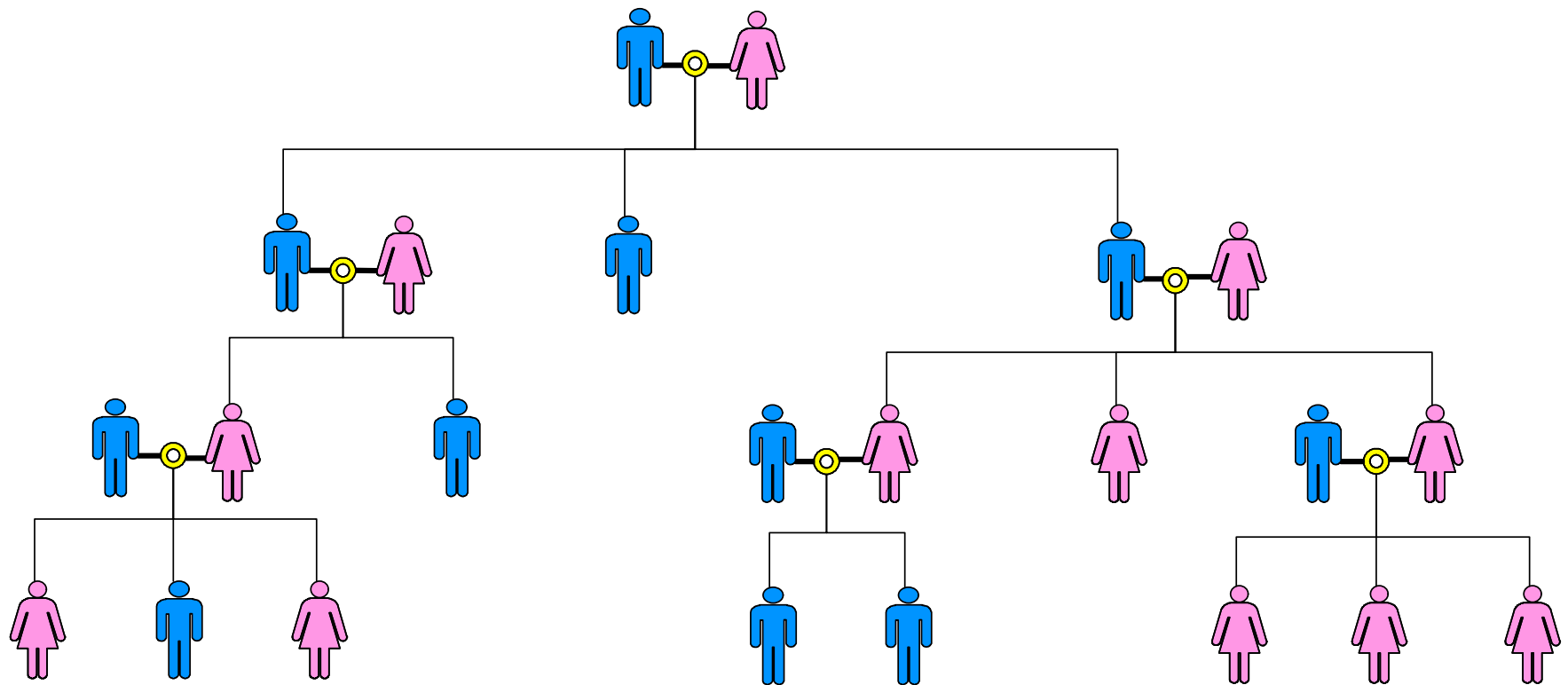
Symbolic Representation



Iconic Representation

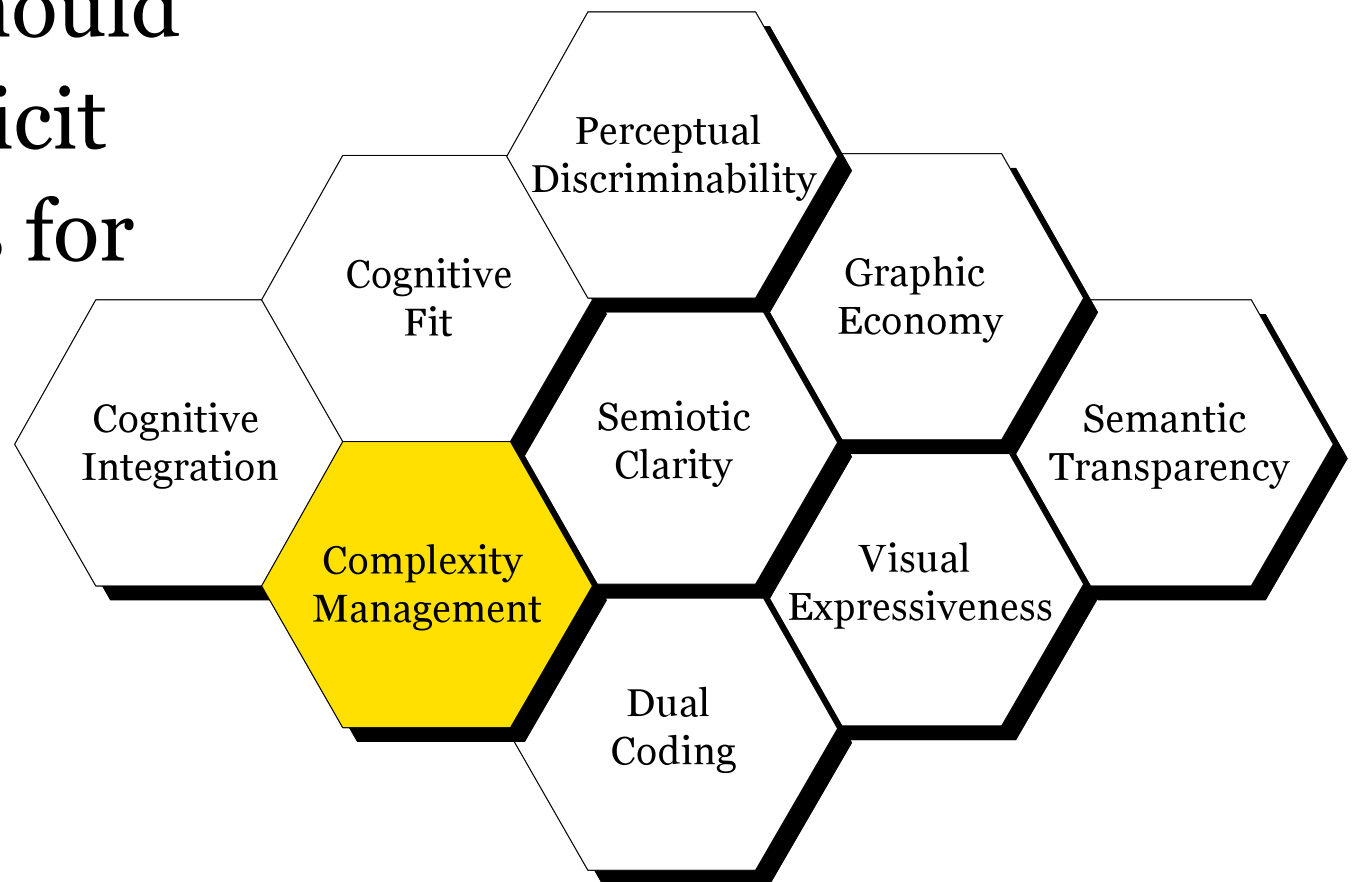


Semantically Transparent (and Redundantly Coded) Representation

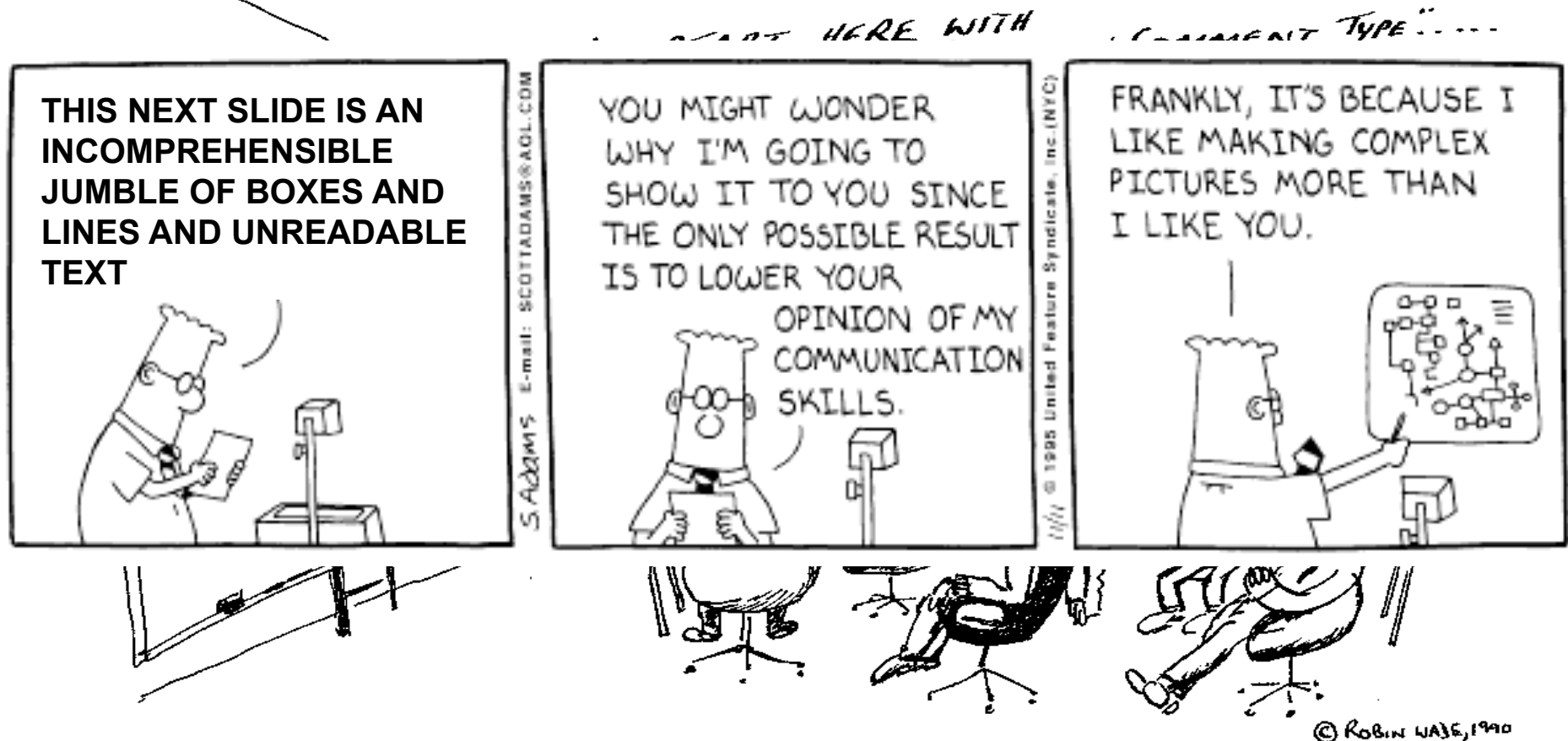


4. Principle of Complexity Management

Notations should include explicit mechanisms for dealing with complexity



The Monolithic Diagram Assumption

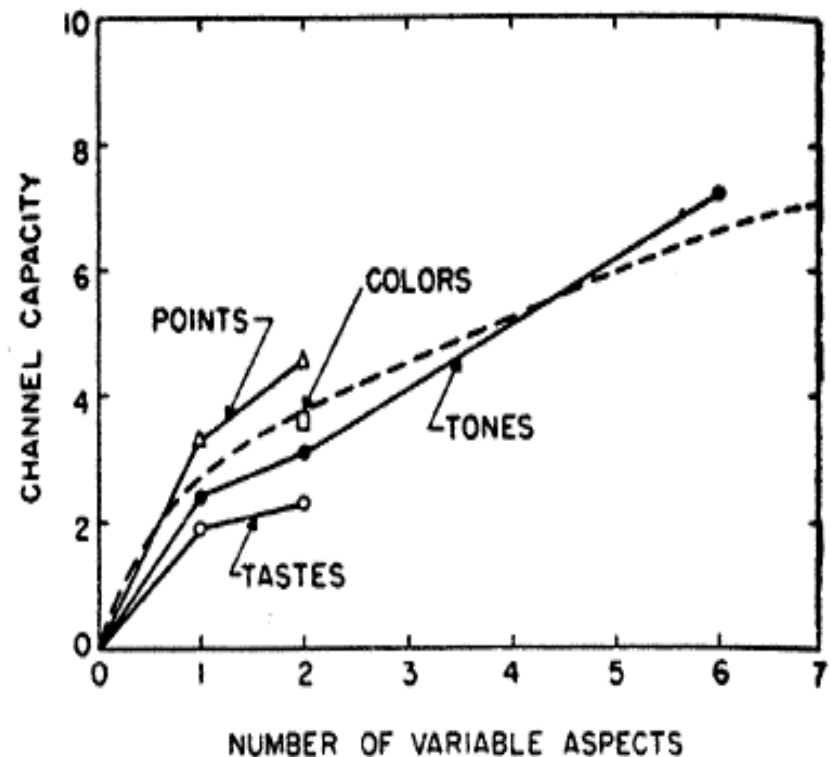


Complexity of diagrams is not a physics problem



“The Magical Number Seven, Plus or Minus Two”

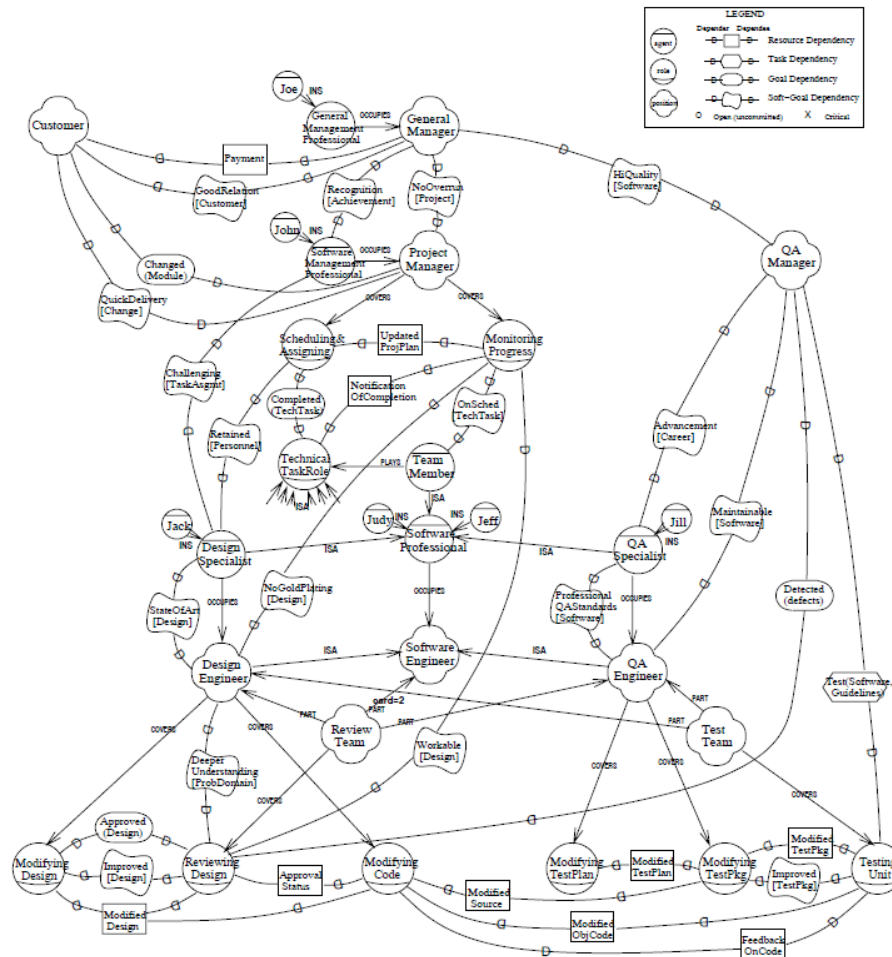
Human channel capacity or “cognitive bandwidth” limited by working memory capacity



Source: Miller, G. A. (1956). The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information. The Psychological Review, 63, 81-97.

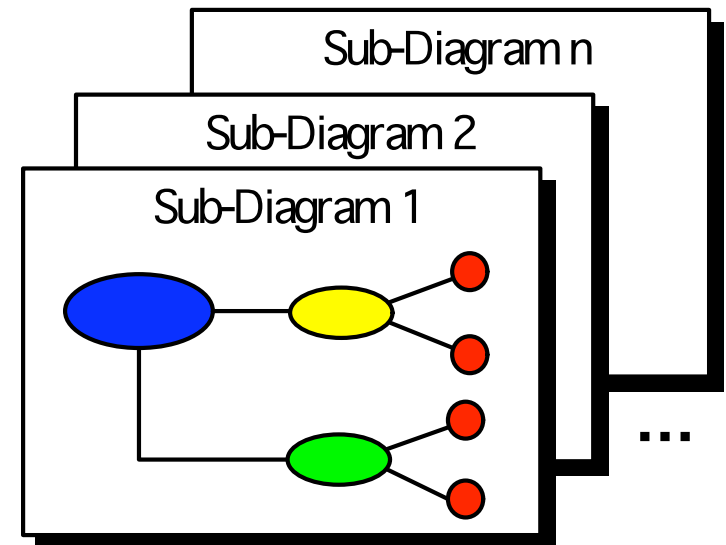
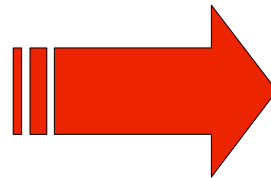
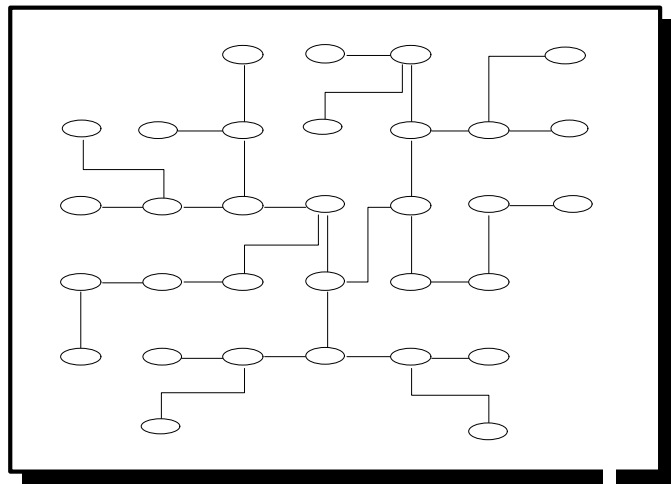


Complexity management in i*

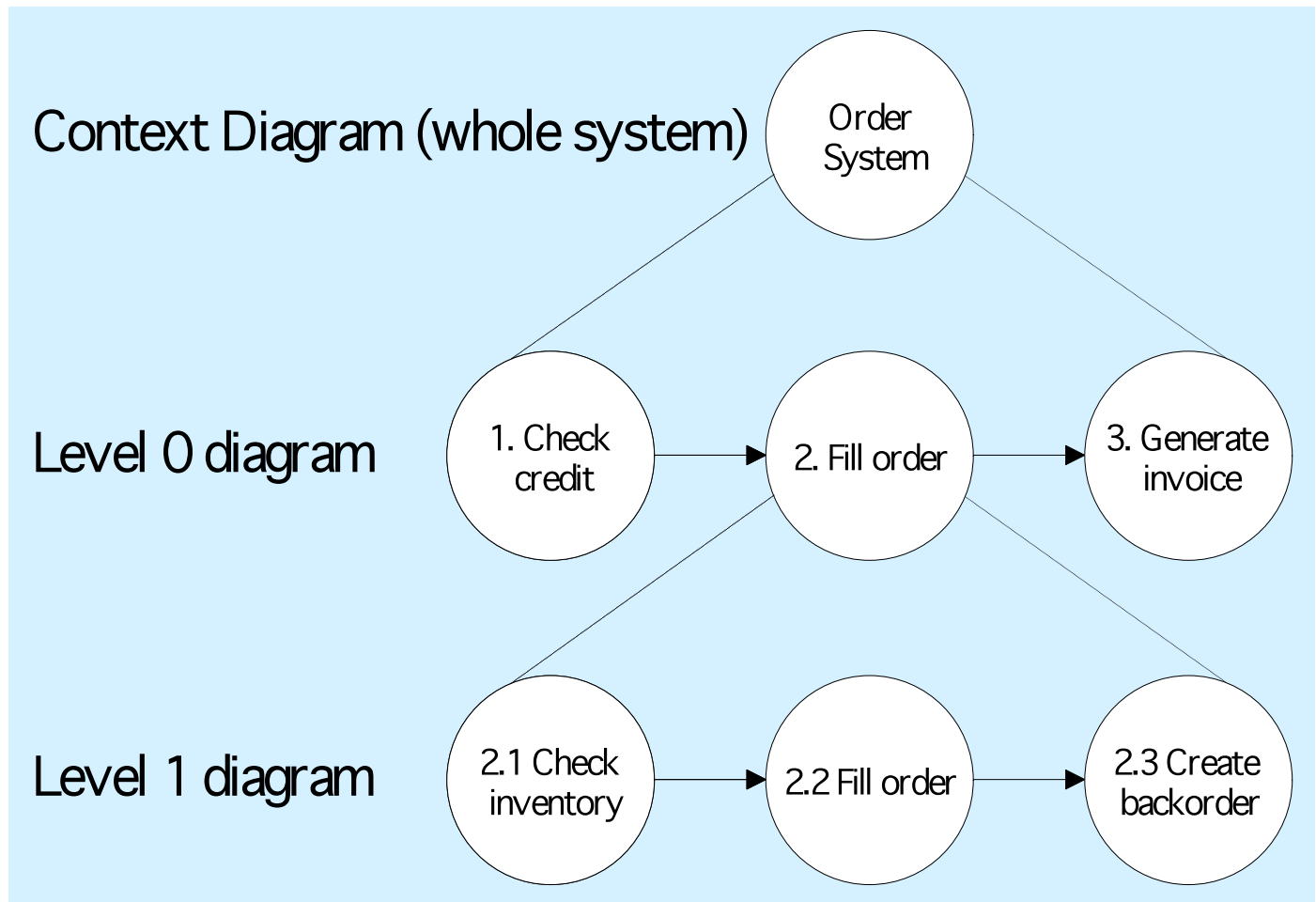


Modularisation

Divide large diagrams into cognitively and perceptually manageable “chunks”

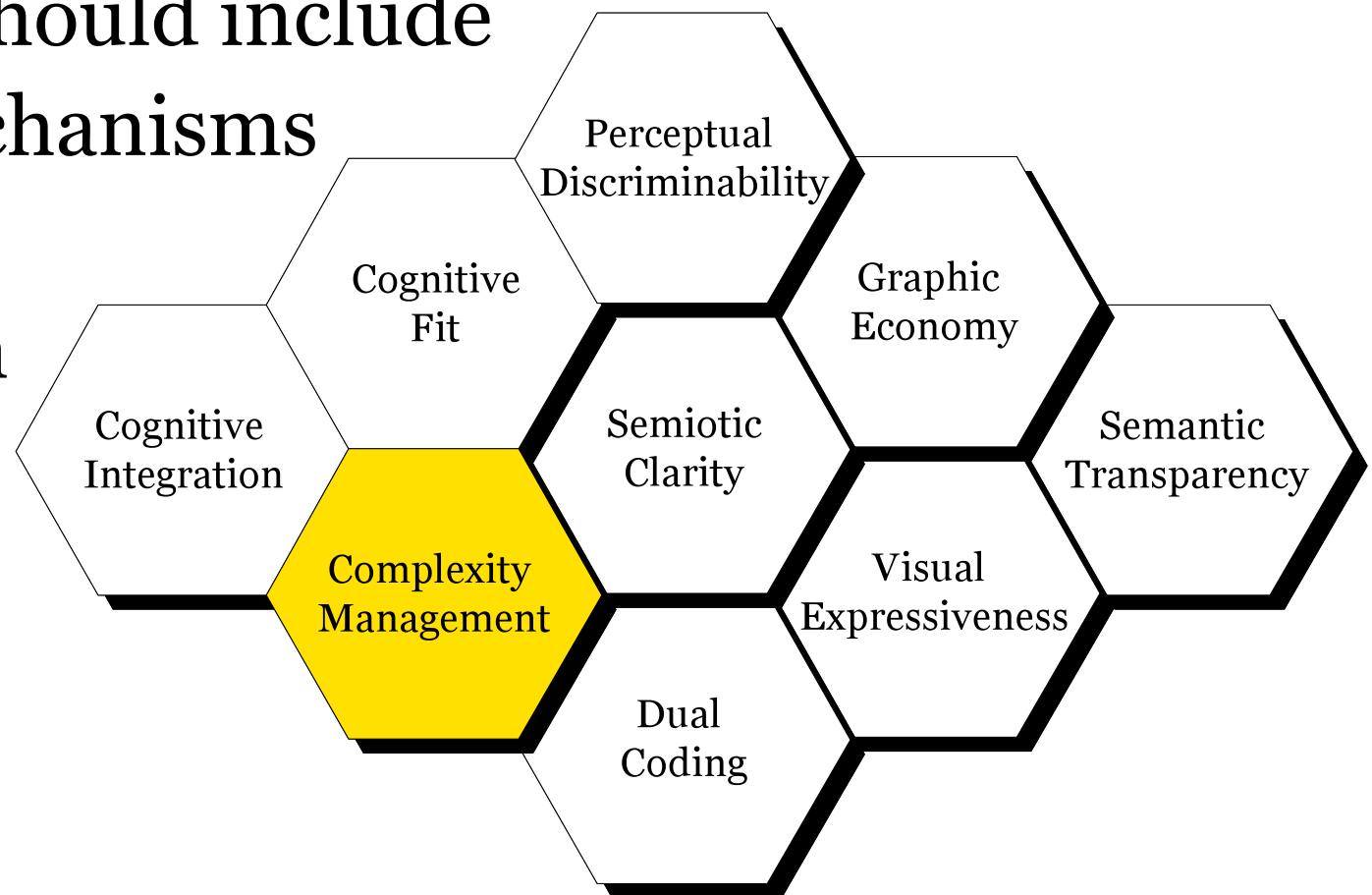


Graphic excellence: DFDs

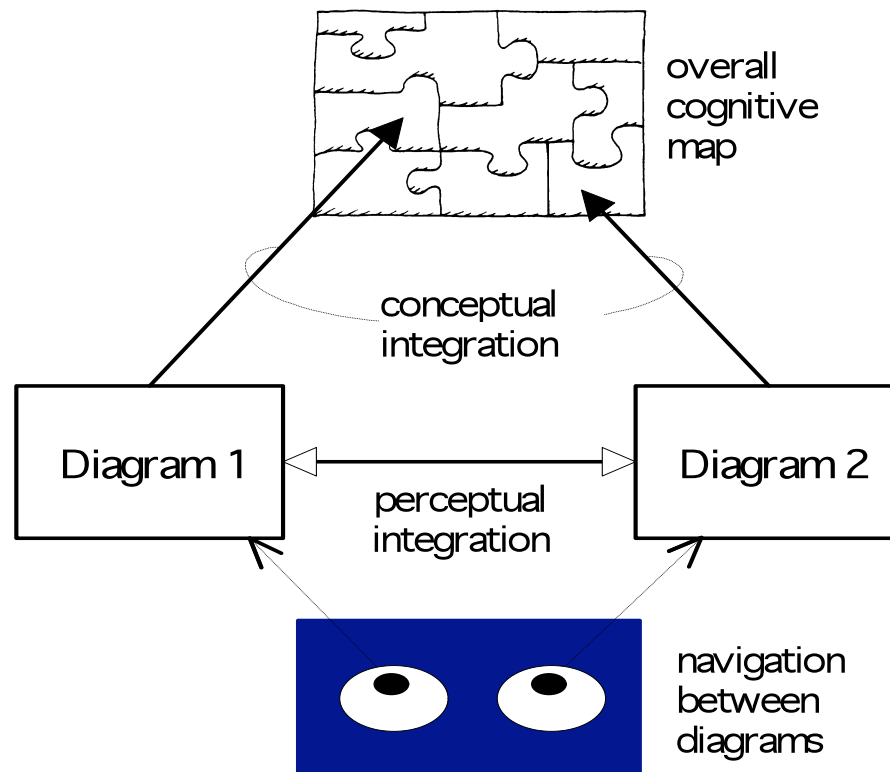


5. Principle of Cognitive Integration

Notations should include explicit mechanisms to integrate information between separate diagrams



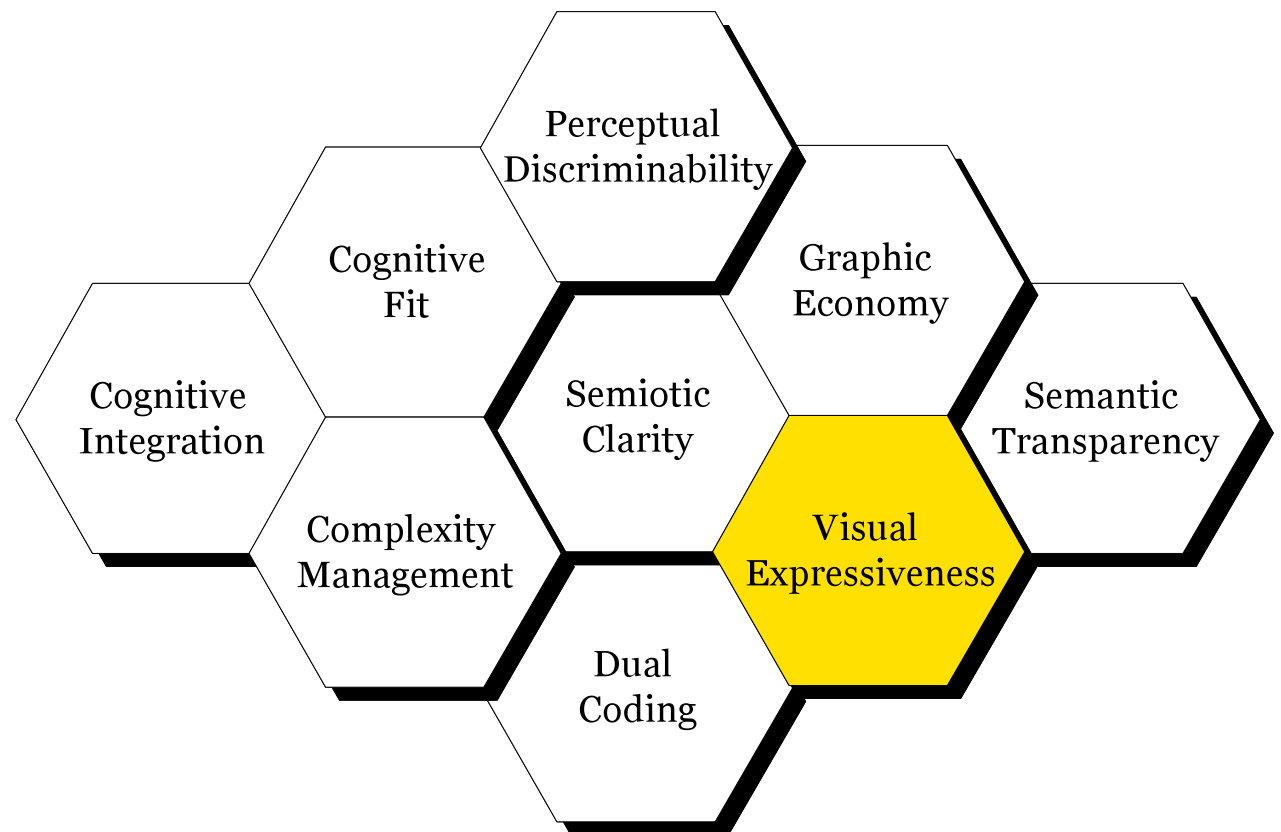
Cognitive Integration Theory



Source: Kim, J., Hahn, J., & Hahn, H. (2000). How Do We Understand a System with (So) Many Diagrams? Cognitive Integration Processes in Diagrammatic Reasoning. *Information Systems Research*, 11(3), 284-303.

6. Principle of Visual Expressiveness

Notations should use the full range of visual variables

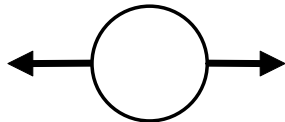


Principle of Visual Expressiveness

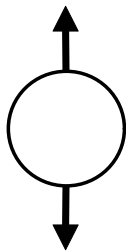
Fully utilise the graphic design space

PLANAR VARIABLES

Horizontal
Position



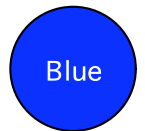
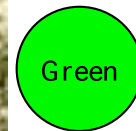
Vertical
Position



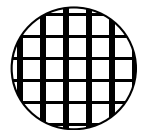
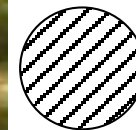
RETINAL VARIABLES



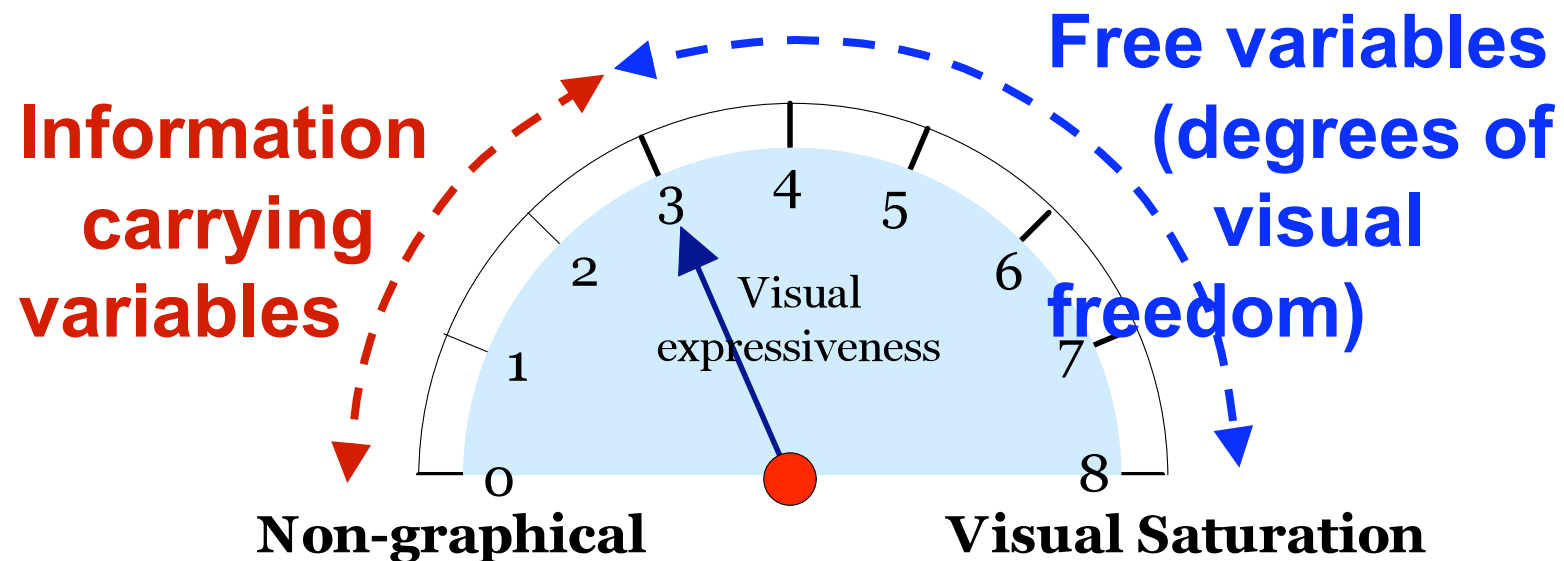
Colour



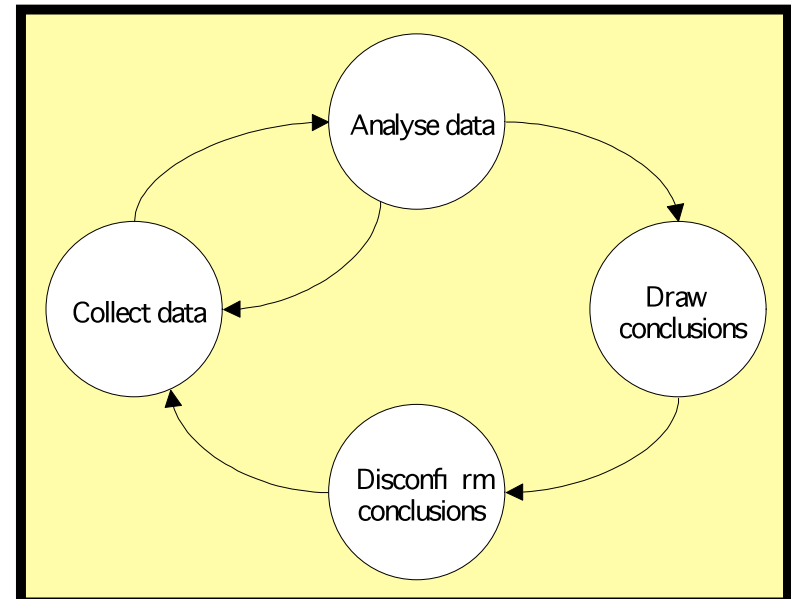
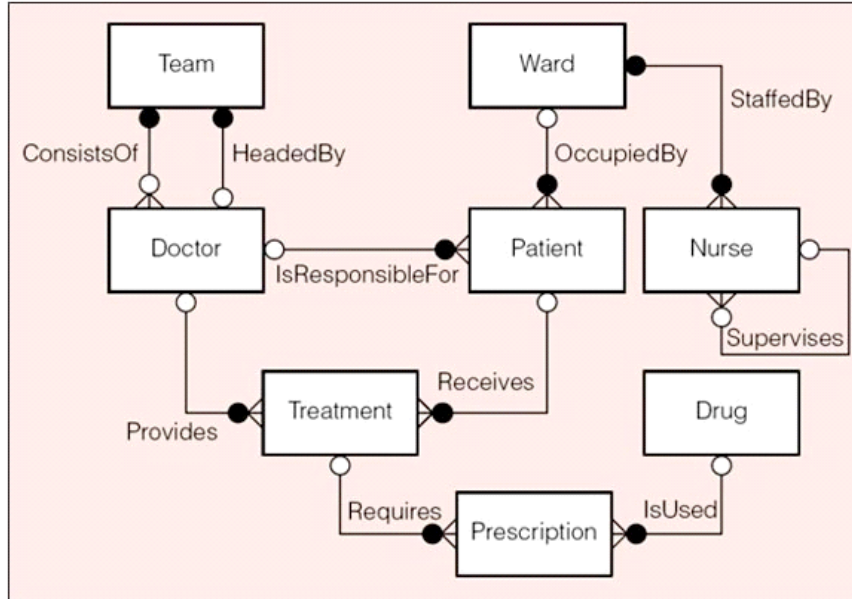
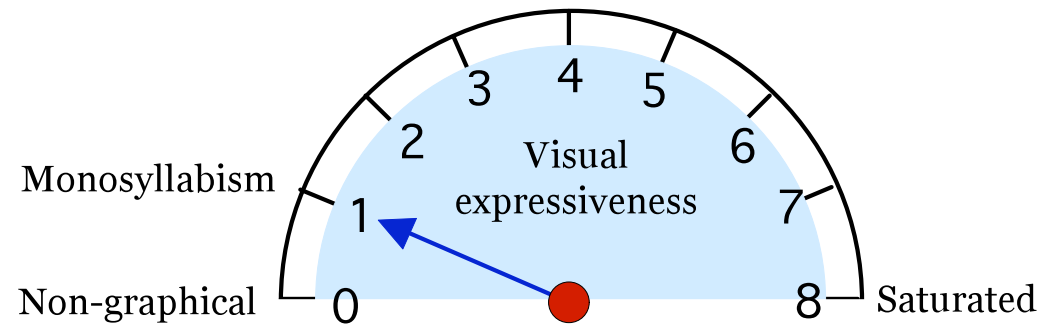
Texture



Visual expressiveness

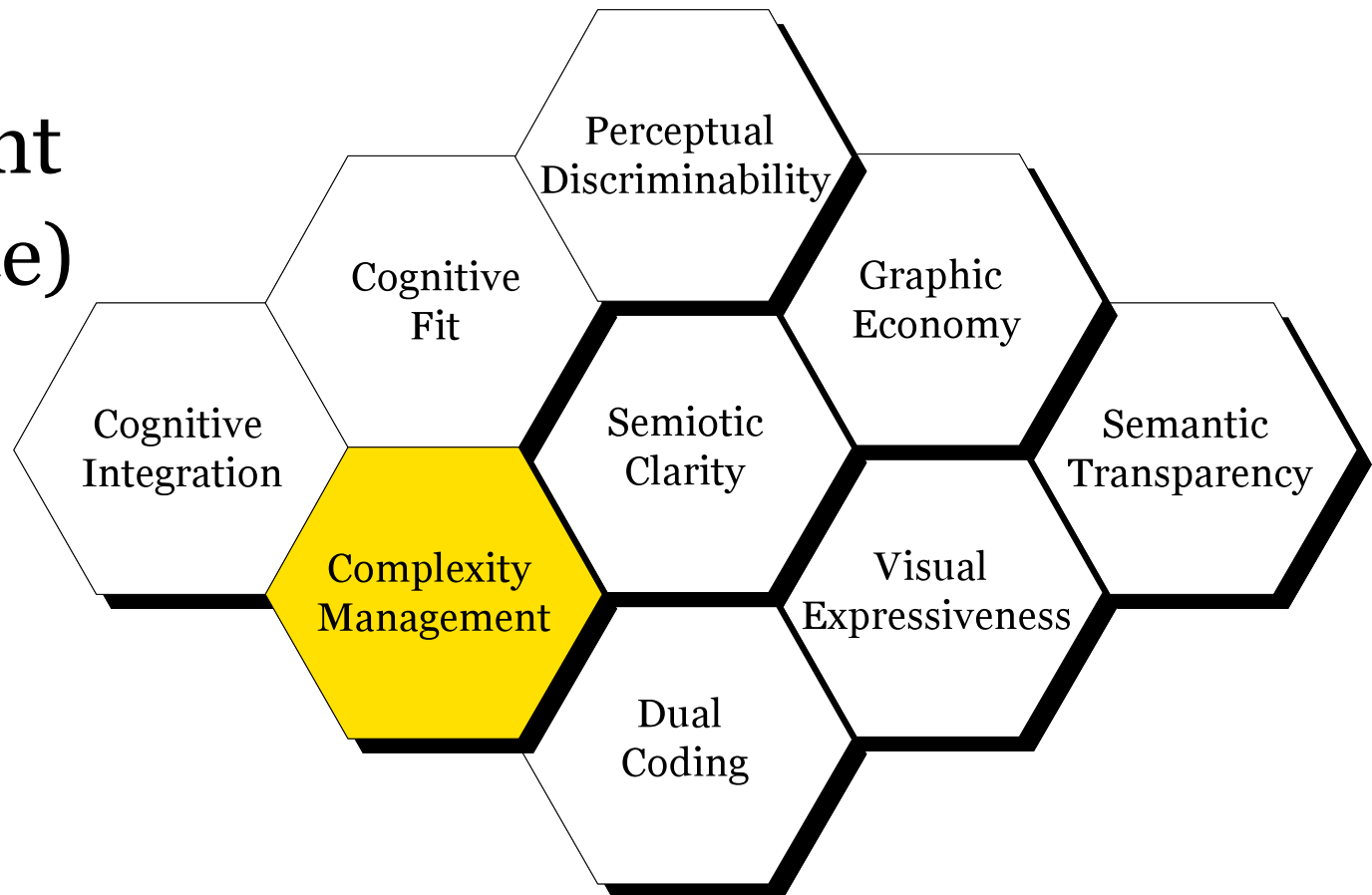


Graphic Mediocrity: Visual Monosyllabism



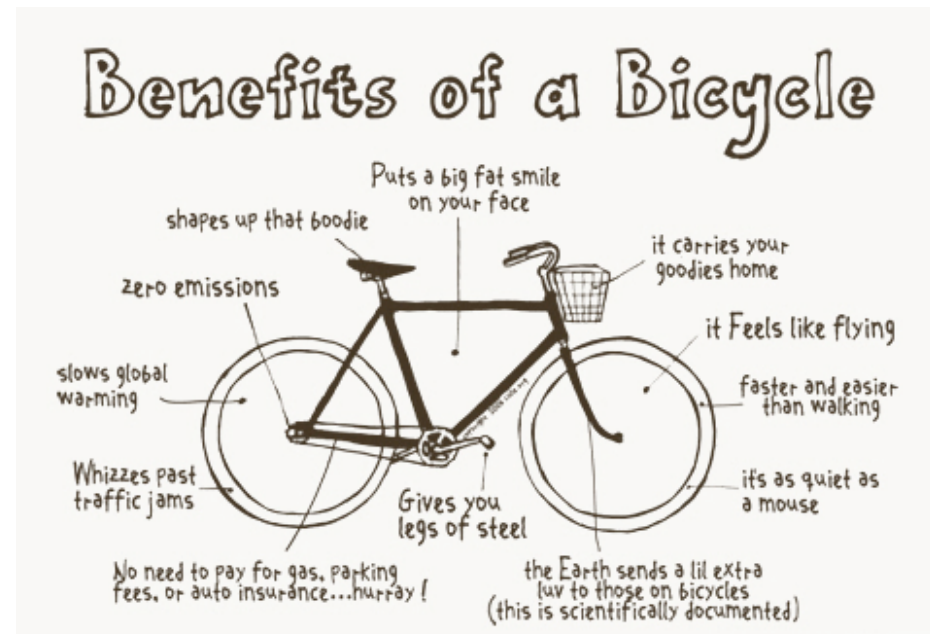
7. Principle of Dual Coding

Use text to
complement
(not replace)
graphics

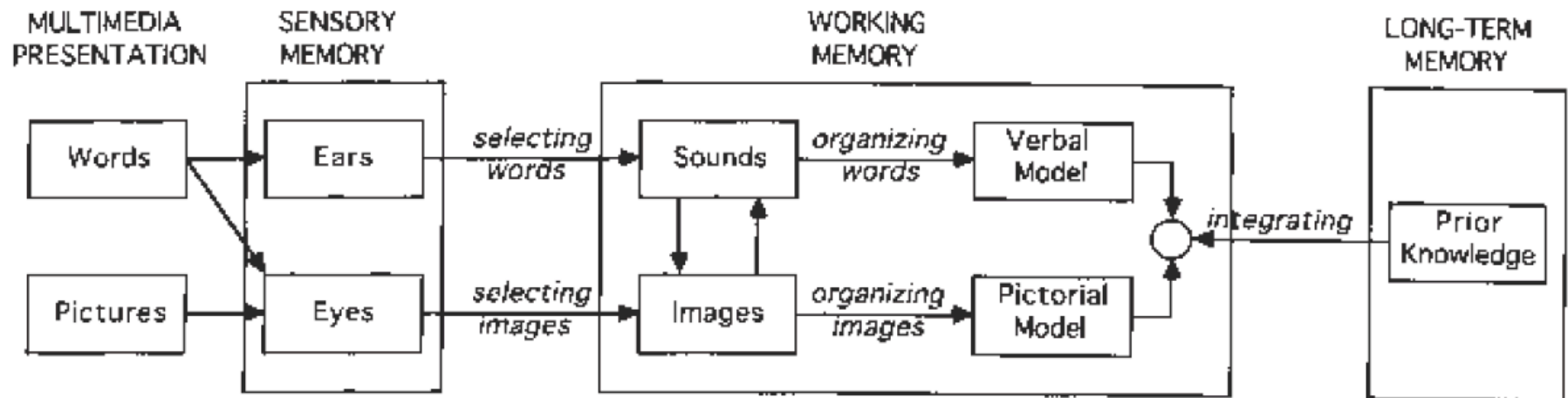


Dual coding (multimedia)

Graphics and text should not be enemies



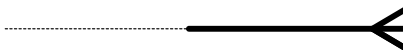


Dual coding theory



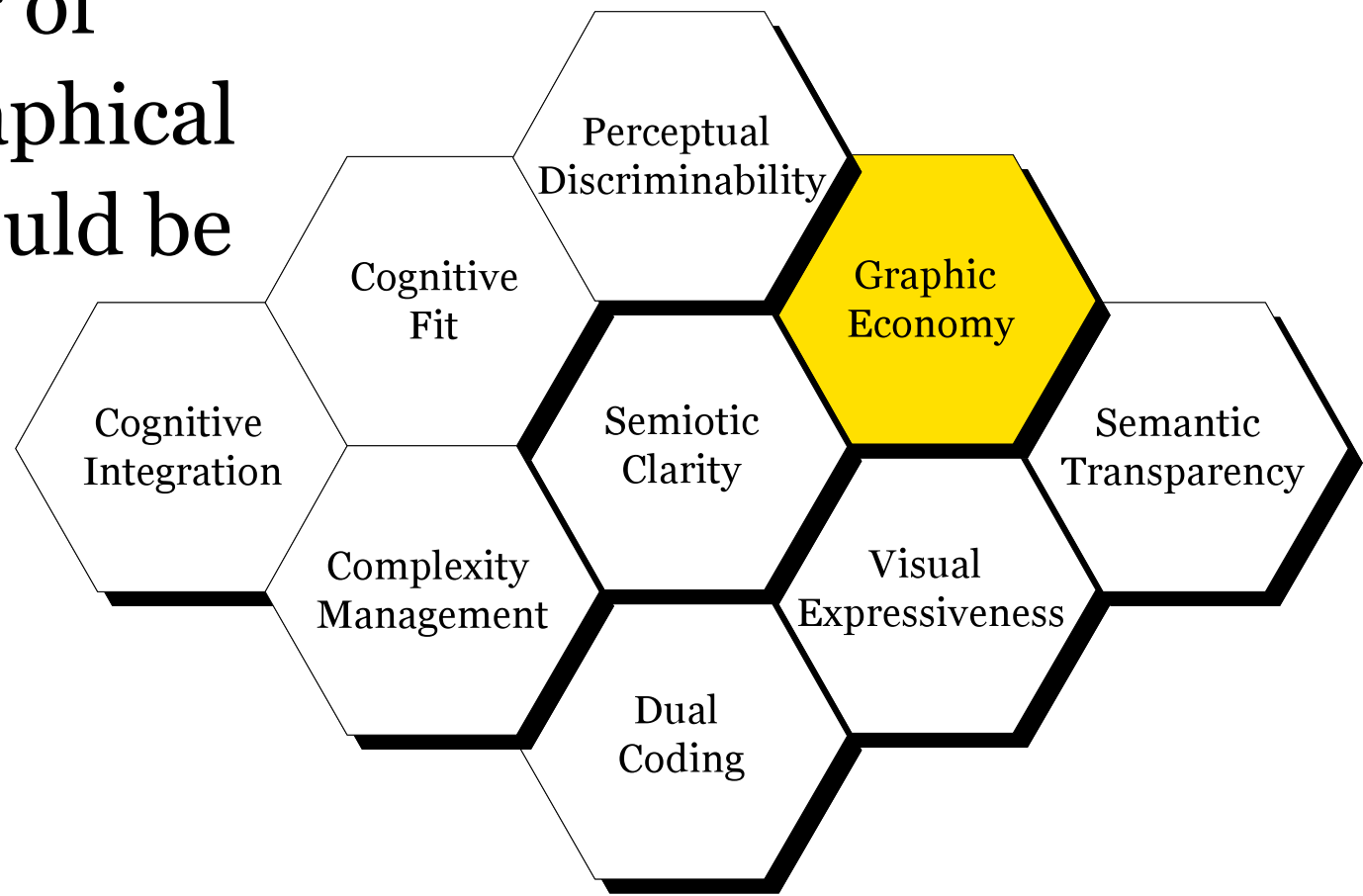
Source: Paivio, A. (1986). *Mental Representations: A Dual Coding Approach*. Oxford, England: Oxford University Press.

Dual coding

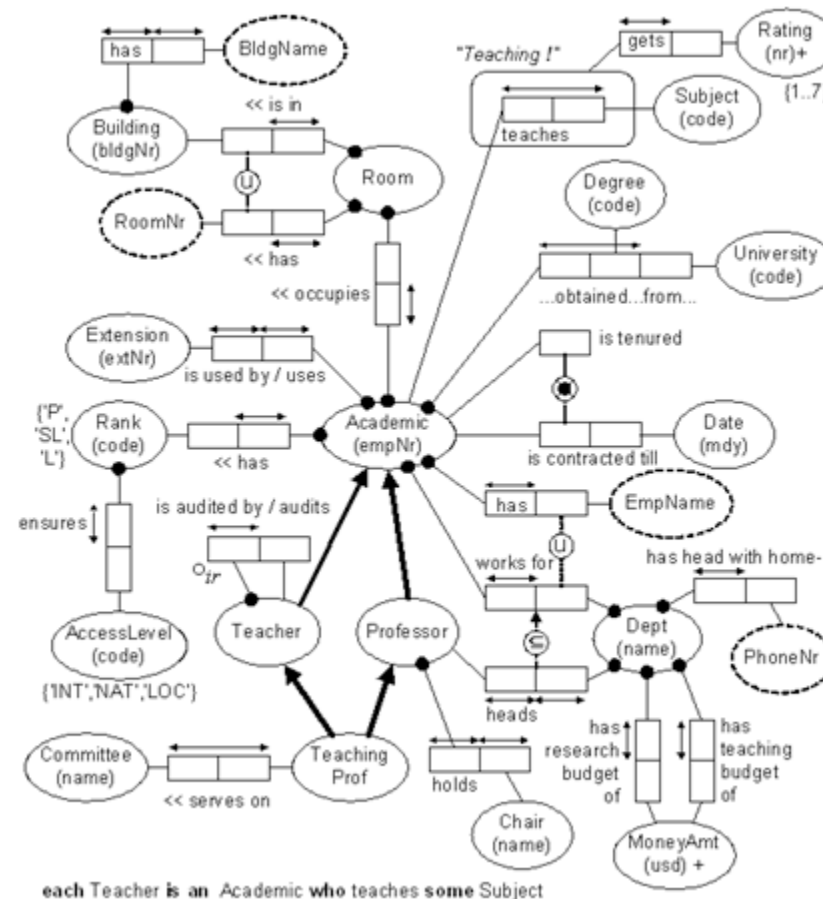
Graphical encoding	Textual encoding	Dual coding
	0..1 3..15 	0..1 3..15 

8. Principle of Graphic Economy (less is more)

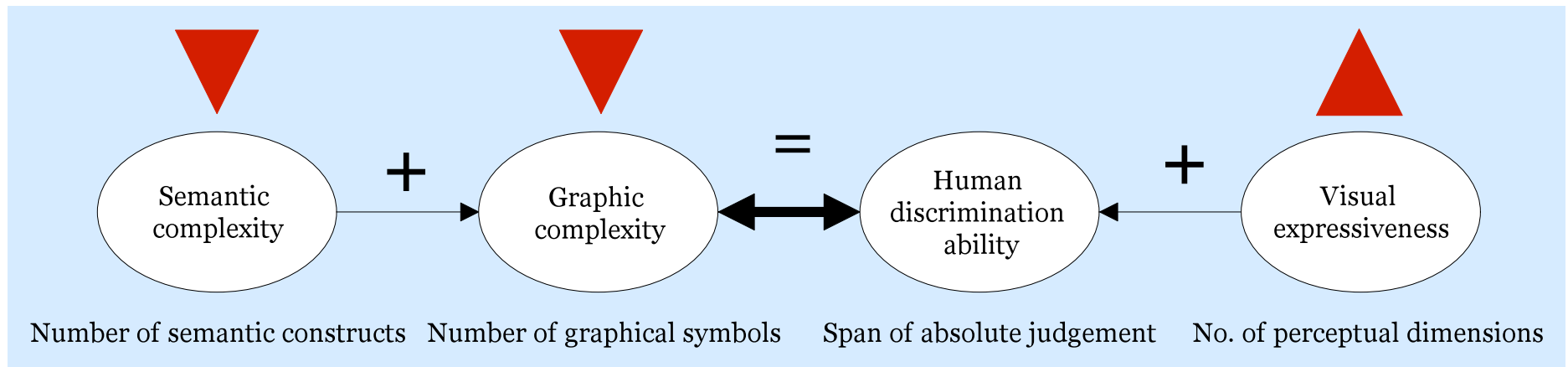
The number of different graphical symbols should be cognitively manageable



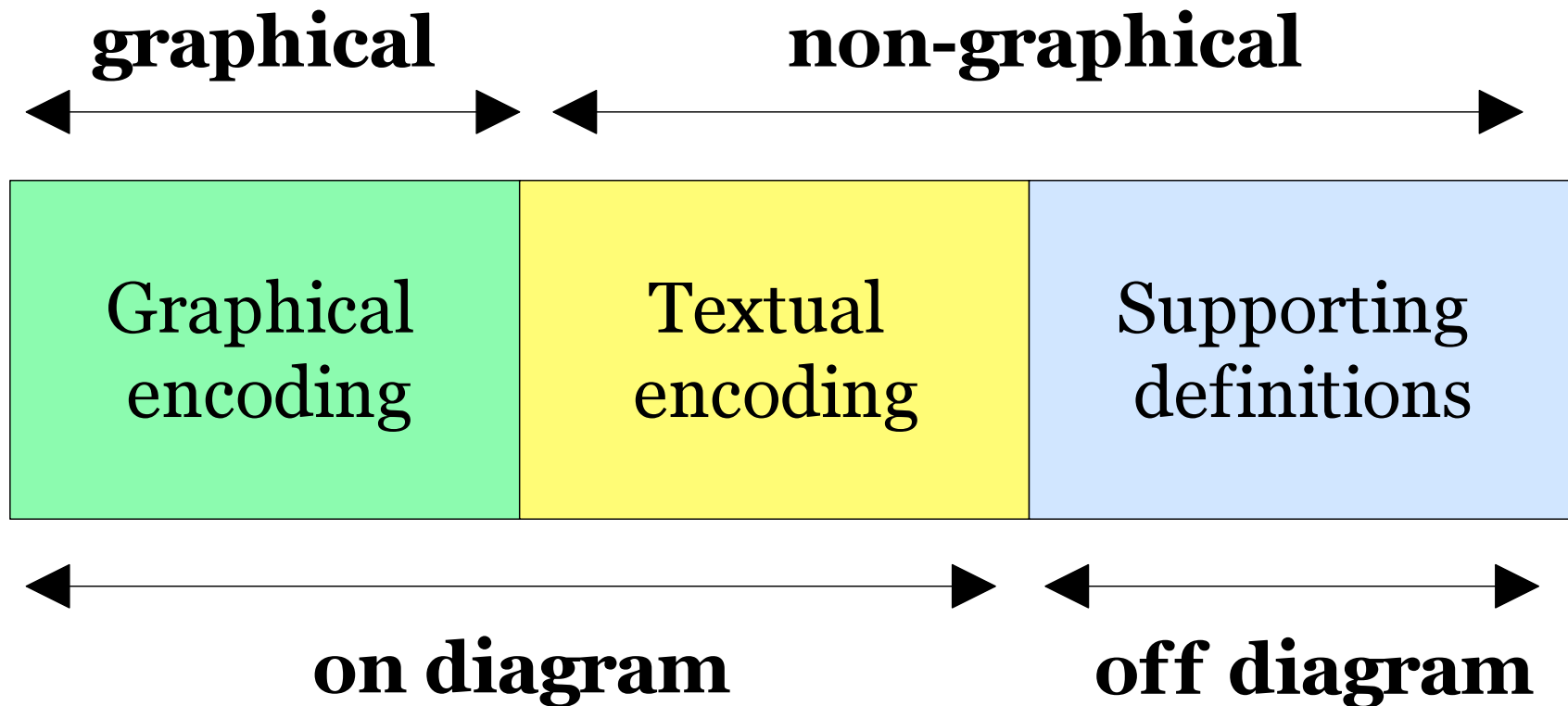
Graphic complexity



Dealing with Graphic Complexity

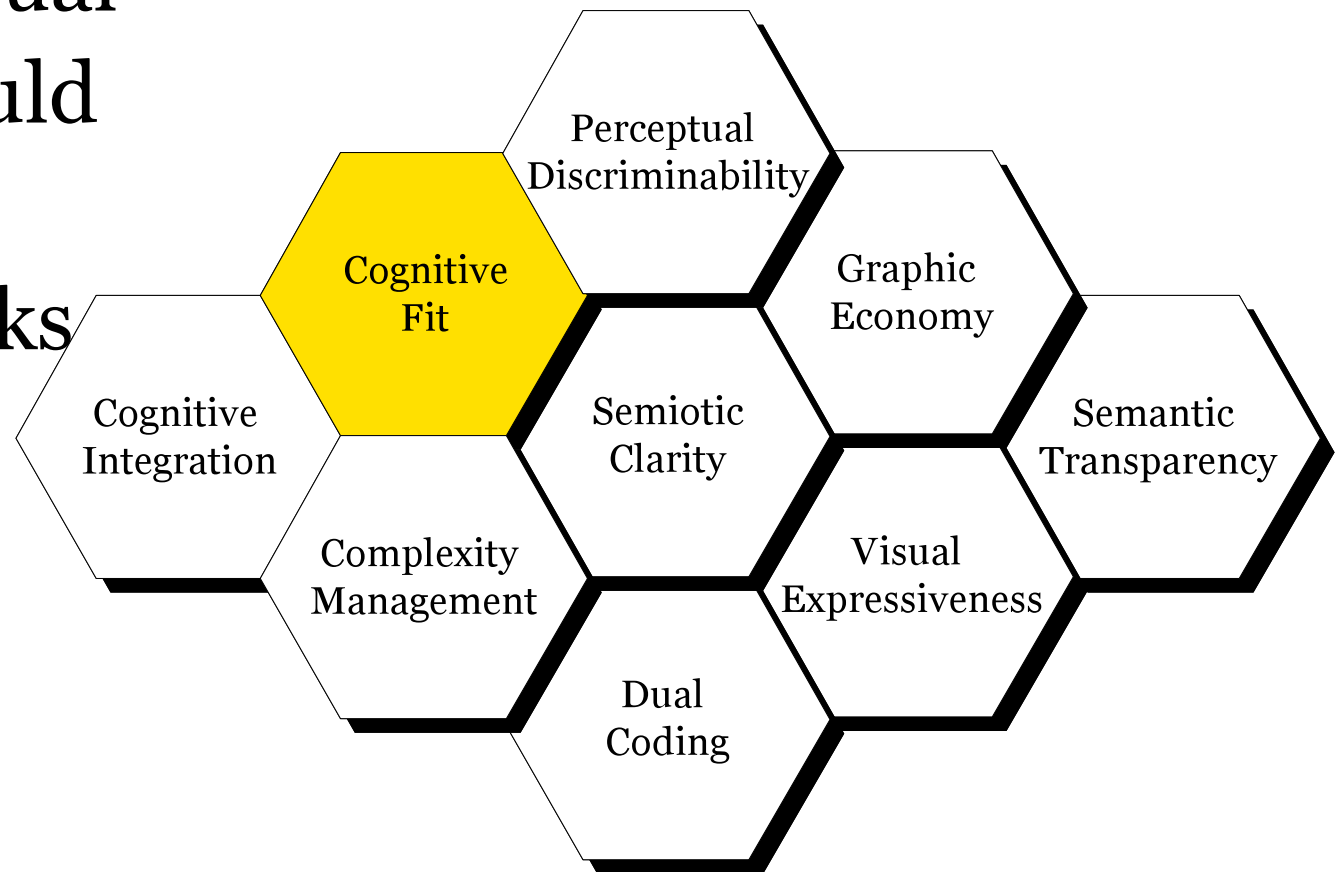


A balancing act

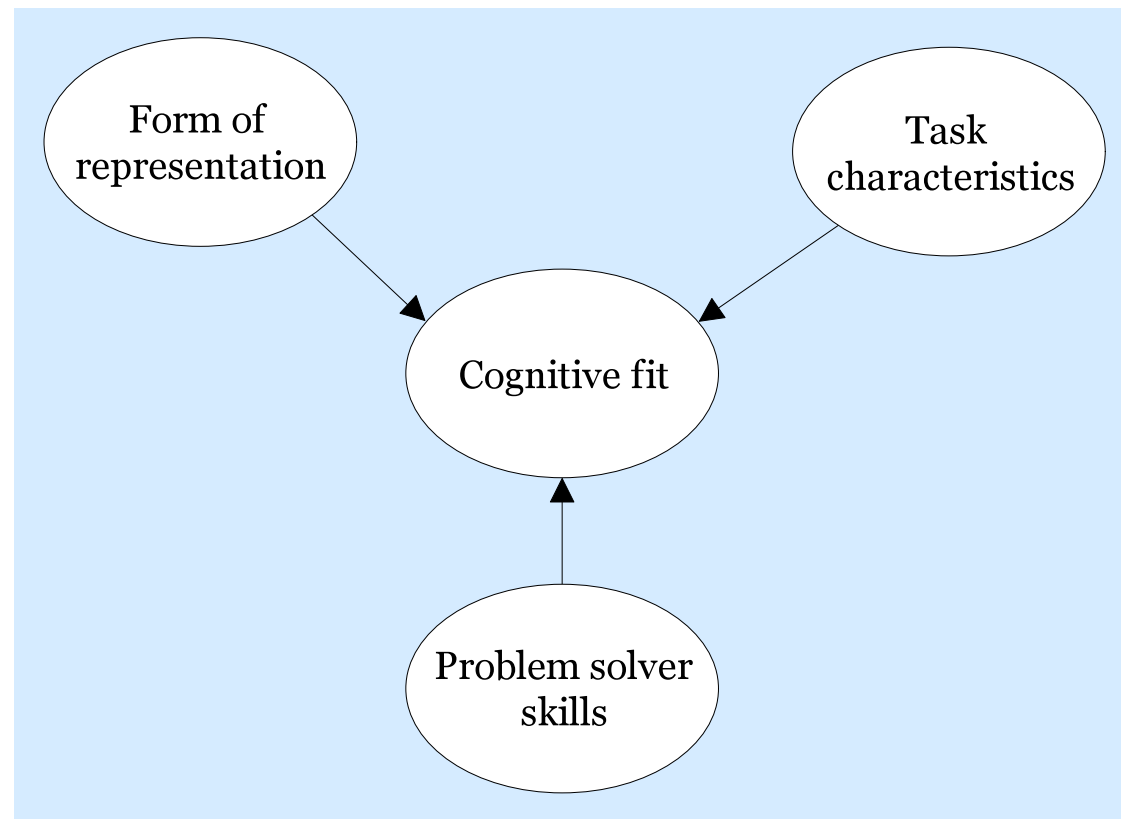


9. Principle of Cognitive Fit (visual horses for cognitive courses)

Different visual dialects should be used for different tasks and/or audiences



Cognitive Fit Theory

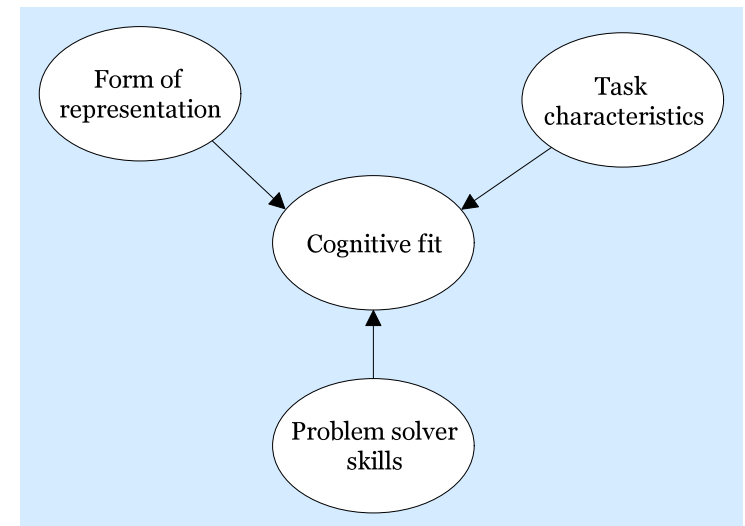


Source: Vessey, I. (1991). "Cognitive Fit: A Theory-based Analysis of the Graphs versus Tables Literature." *Decision Sciences* 22: 219-240.

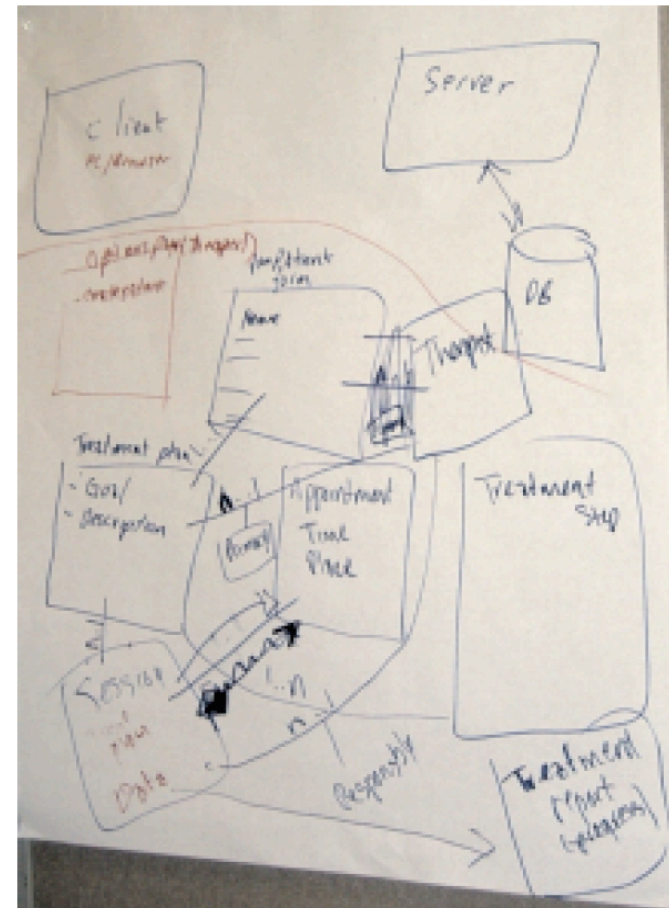
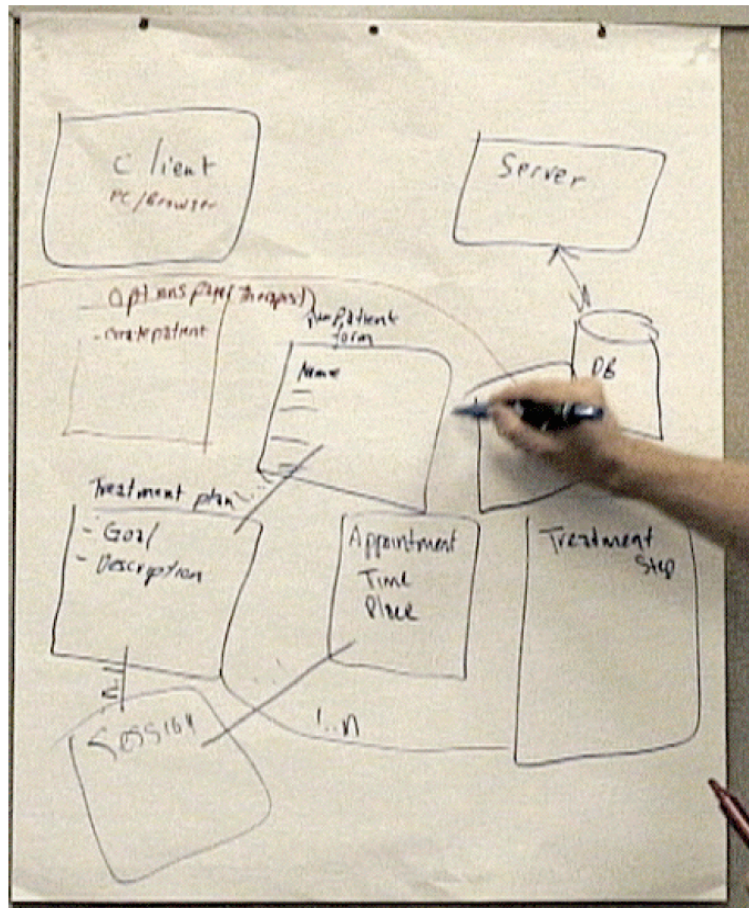
Expert-Novice differences

Novices lack **schemas** for decoding diagrams

- ★ Meaning of symbols
- ★ Discrimination between symbols
- ★ Complexity
- ★ Visual noise
- ★ Processing strategies



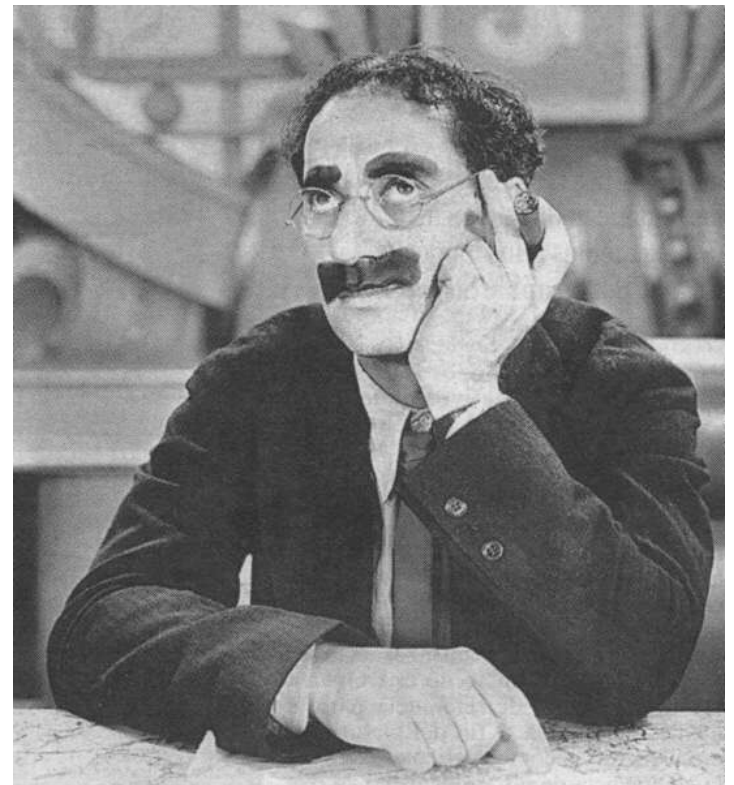
Representation medium (or production method)



Principles

Those are my principles, and if you don't like them... well, I have others.

-- Groucho Marx



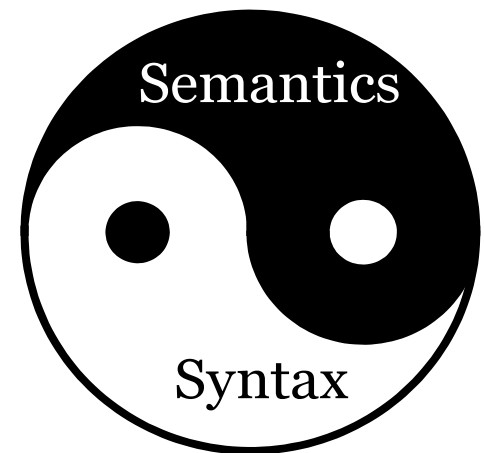
The “Physics” of Notations: A Scientific Approach to Designing Visual Notations

1. The Nature of Visual Notations
2. The State of the Art
3. Previous Research
4. How Visual Notations Communicate
5. Principles for Visual Notation Design
6. Conclusion

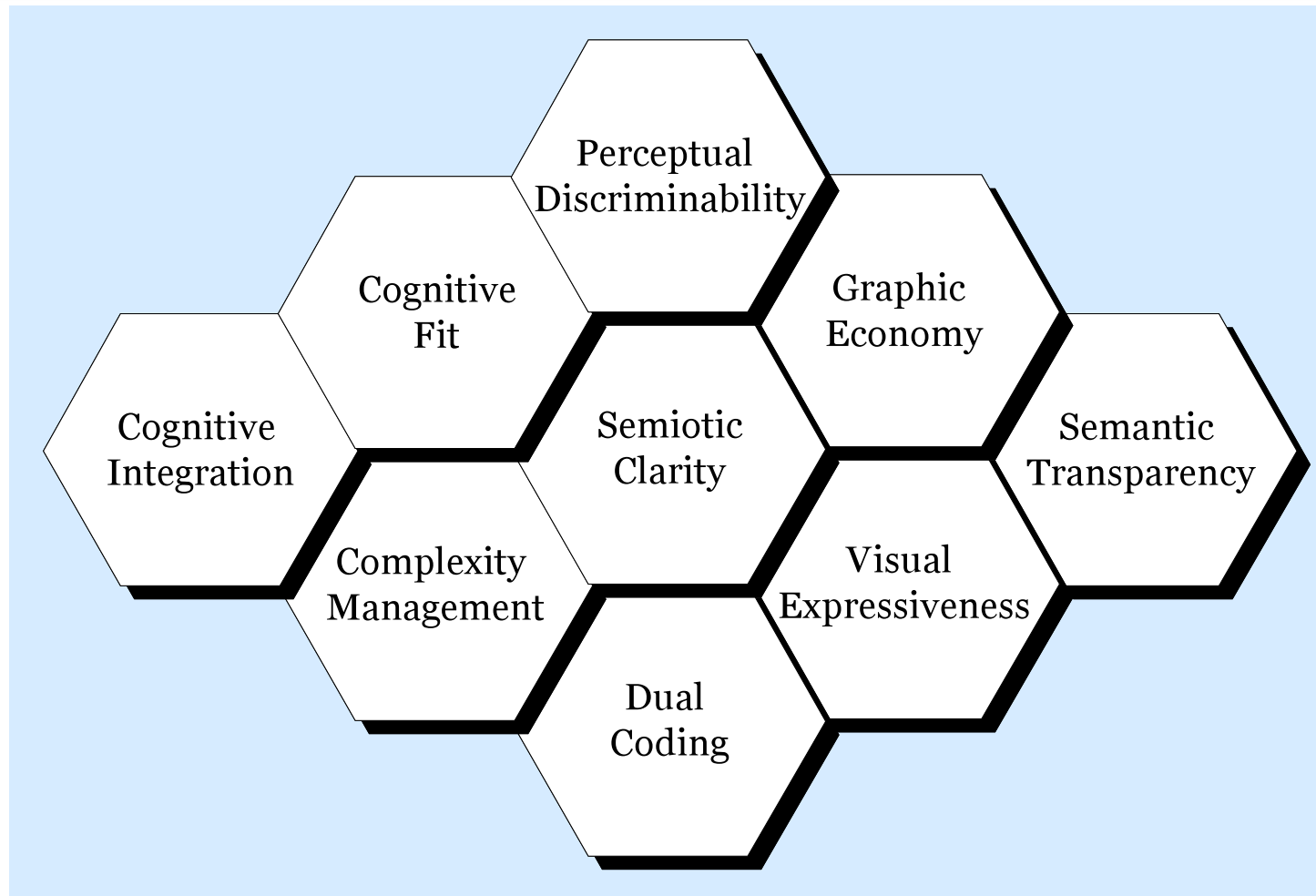
Conclusion

Design of visual syntax

- ★ Determines usability and effectiveness of notations
- ★ Requires significant effort, attention and expertise
- ★ Requires explicit design rationale
- ★ Should be evidence-based



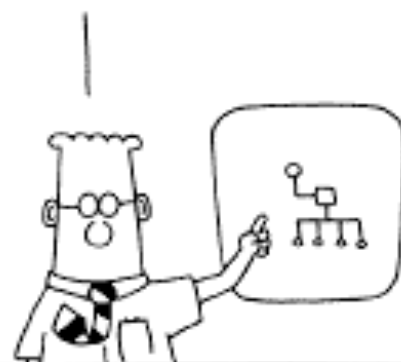
Prescriptive Theory: Principles for Cognitively Effective Visual Notations



Applications of Principles

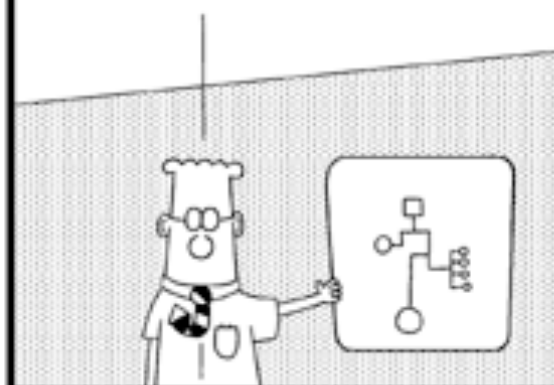
- ★ Constructing visual notations
- ★ Evaluating and improving visual notations
- ★ Comparing visual dialects
- ★ Generating new visual forms

ARE THERE
ANY QUESTIONS?



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THIS COMPLETES MY
PRESENTATION.



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DO YOU EVER FEEL
ALONE WHEN YOU'RE
WITH PEOPLE?

I TRY
TO.



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