



Open Innovation Platform
University - Enterprise
Collaboration

Inventive Product Design and Advanced TRIZ

Design Creativity and Innovation in
Complex Multi-Disciplinary Projects

LUT Summer School
July 25-29, 2016

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Co-funded by the
Erasmus+ Programme
of the European Union



Outline

Design models

- Classification schemes
- Forms of reasoning
- FBS Design Ontology

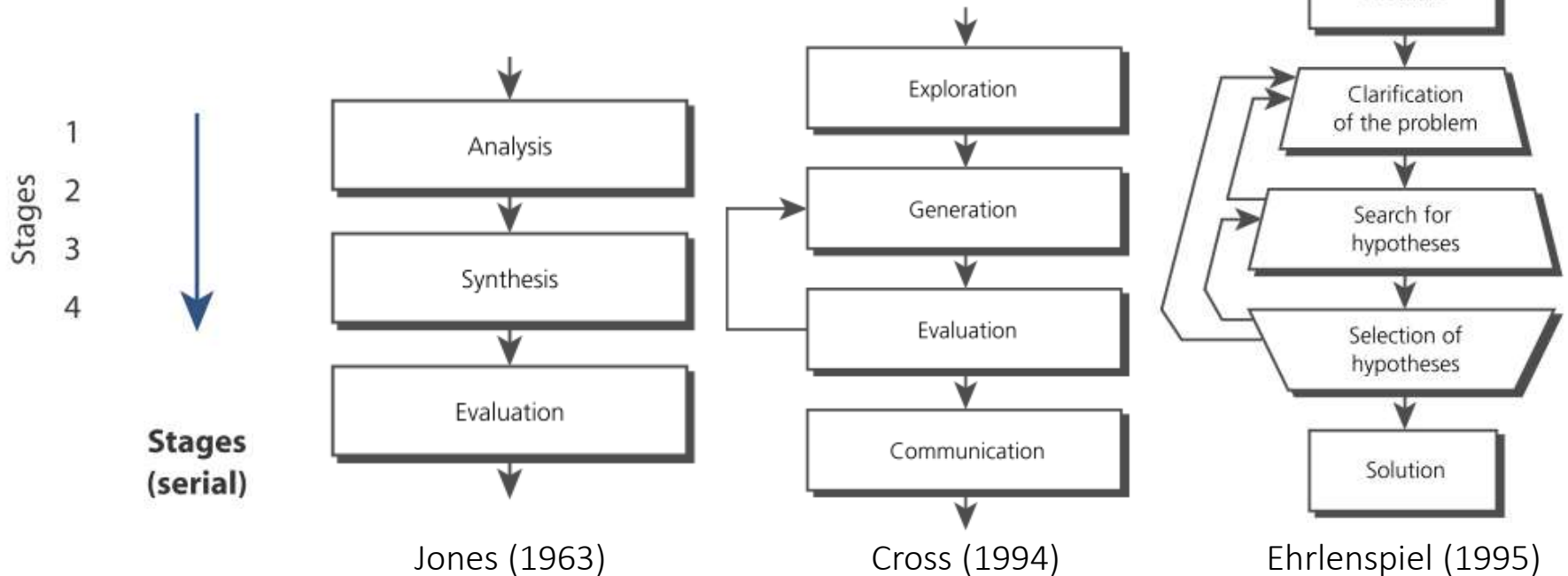
Observing design activities

- Design Protocol analyses
- Factors affecting design creativity

Design Models

Classification schemes

- Stage-based vs Activity-based Models
- Stage-based structure of the project life-cycle
- Iterative problem-solving process

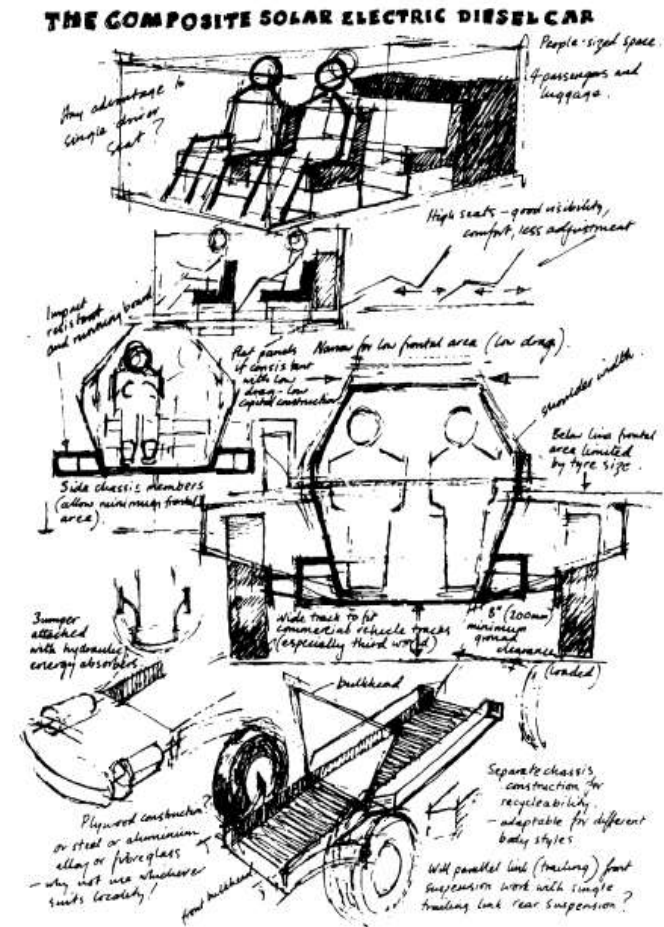


Design Models

Classification schemes

- Solution-oriented vs Problem-oriented

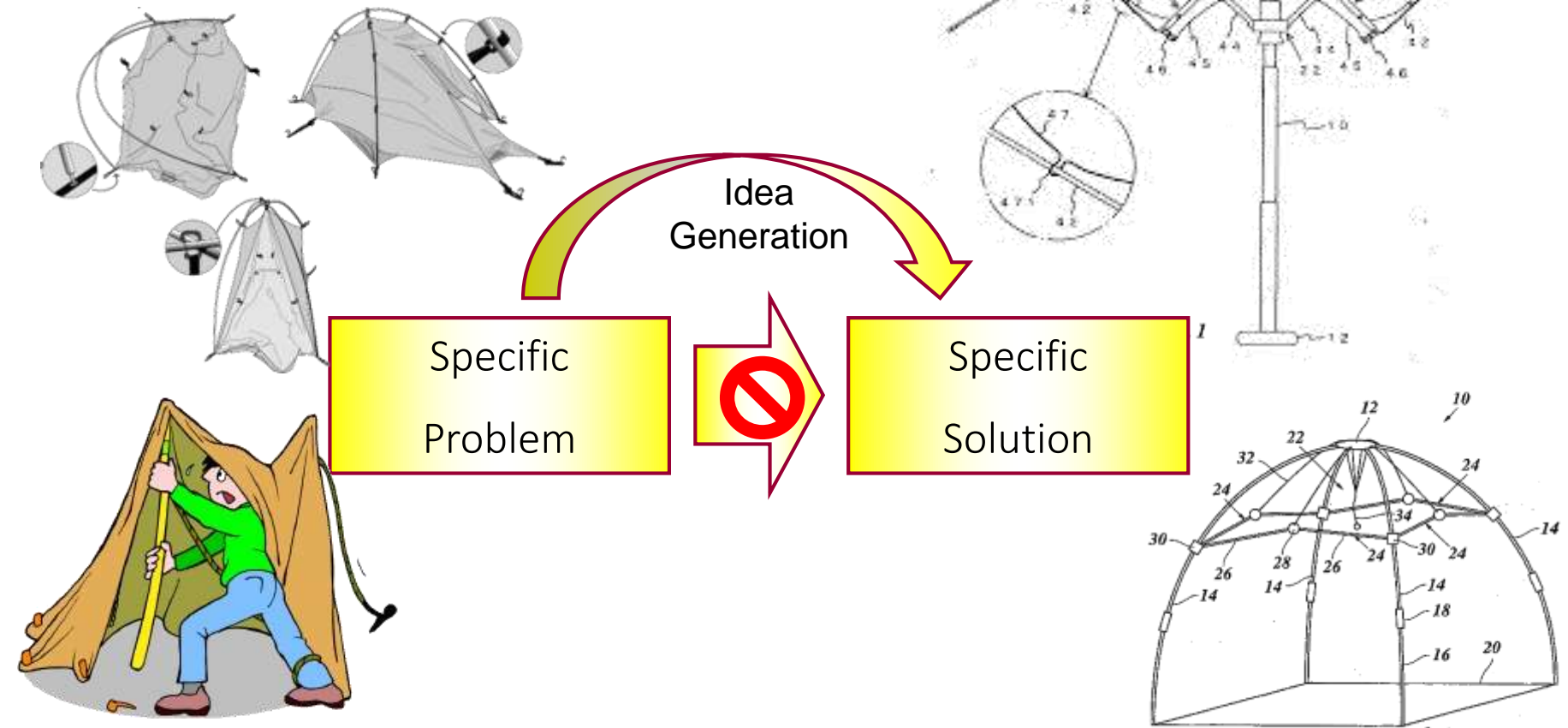
- ❖ **Solution-oriented,**
 - an initial solution is proposed, analyzed and repeatedly modified as the design space and requirements are explored together
- ❖ **Problem-oriented,**
 - emphasis is placed upon abstraction and thorough analysis of the problem structure before generating a range of possible solutions



Design Models

Classification schemes

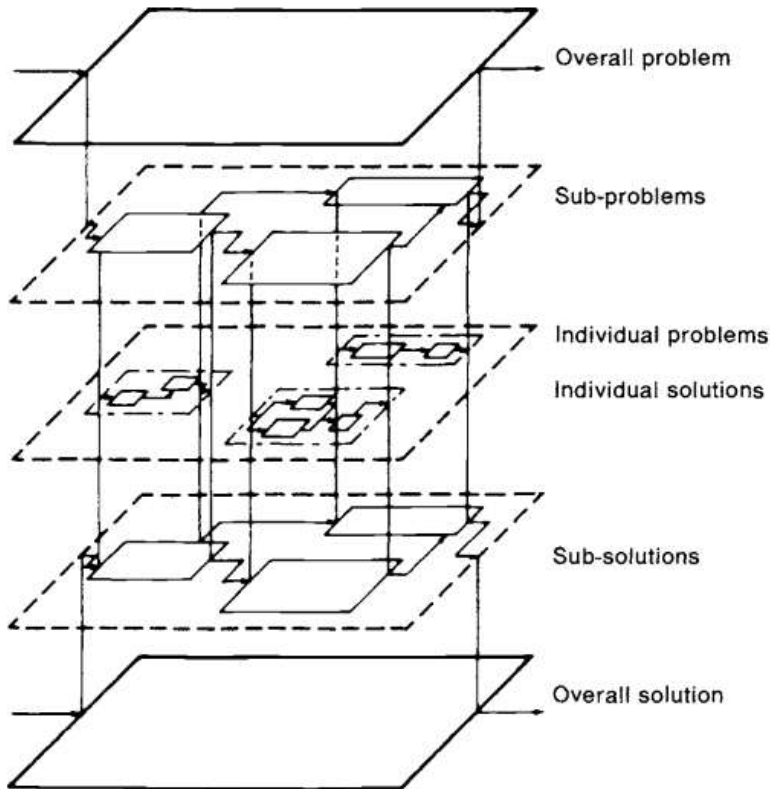
- Problem-oriented approaches



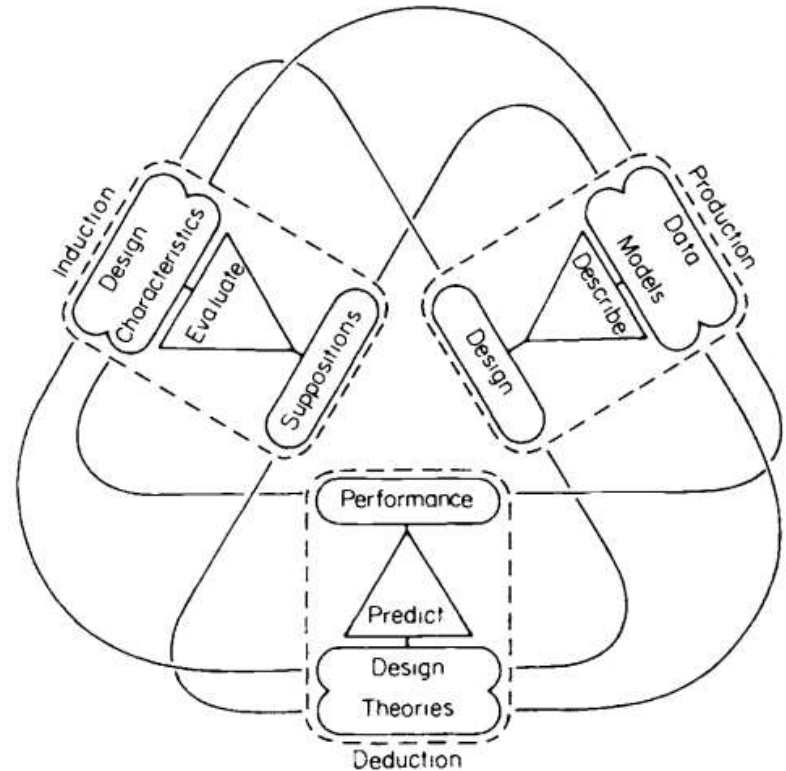
Design Models

Classification schemes

- Abstract models



VDI 2221



March (1984)

Design Models

Forms of reasoning

- **Deduction:** Derive a conclusion from given axioms (“knowledge”) and facts (“observations”).
- Example:

All humans are mortal.

(axiom)

Socrates is a human.

(fact/ premise)

Therefore, it follows that Socrates is mortal.

(conclusion)

- The conclusion can be derived by applying the *modus ponens* inference rule (Aristotelian logic).
- Theorem proving is based on deductive reasoning techniques.



Design Models

Forms of reasoning

- **Induction:** Derive a general rule (axiom) from background knowledge and observations.
- Example:



Socrates is a human

(background knowledge)

Socrates is mortal

(observation/ example)

Therefore, I hypothesize that all humans are mortal (generalization)

- Remarks:
 - Induction means to infer generalized knowledge from example observations: Induction is *the* inference mechanism for (machine) learning.

Design Models

Forms of reasoning

- **Abduction:** From a known axiom (theory) and some observation, derive a premise.
- Example:

All humans are mortal

(theory)

Socrates is mortal

(observation)

Therefore, Socrates must have been a human

(diagnosis)



Design Models

The FBS Ontology

Function-Behavior-Structure (FBS) [1]:

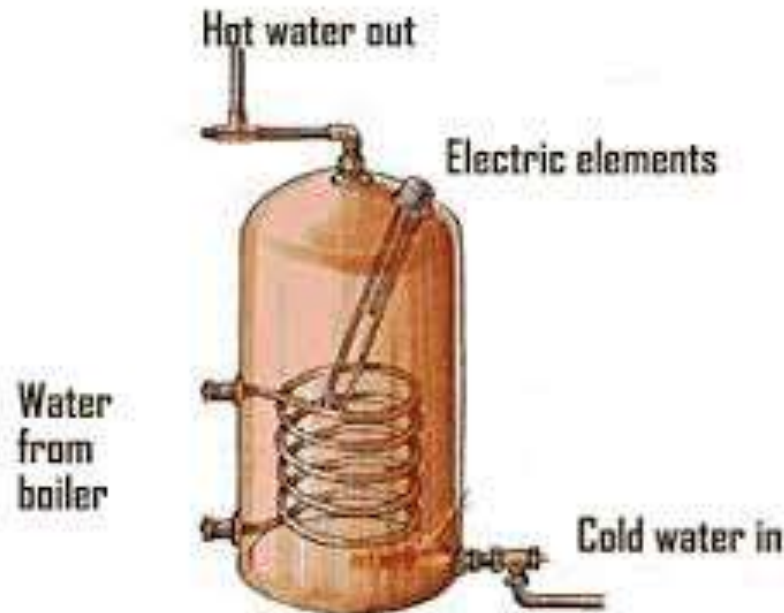
- The **Function** of a Technical System TS is the motivation for its existence;
 - at the **Structure** level, a TS is constituted by entities, attributes of these entities and relations among them;
 - the **Behavior**, defined as sequential changes of objects state governed by the Laws of Nature, is the link between Function and Structure.
-
- Different Behaviors can produce the same Function
 - Different Structures can be characterized by the same Behavior

[1] Gero, J.S. and Rosenman, M.A.: "A conceptual framework for knowledge based design research at Sydney University's Design Computing Unit". Artificial Intelligence in Engineering, 5(2), 1990, 65-77.

Design Models

The FBS Ontology (Gero et al., 1990)

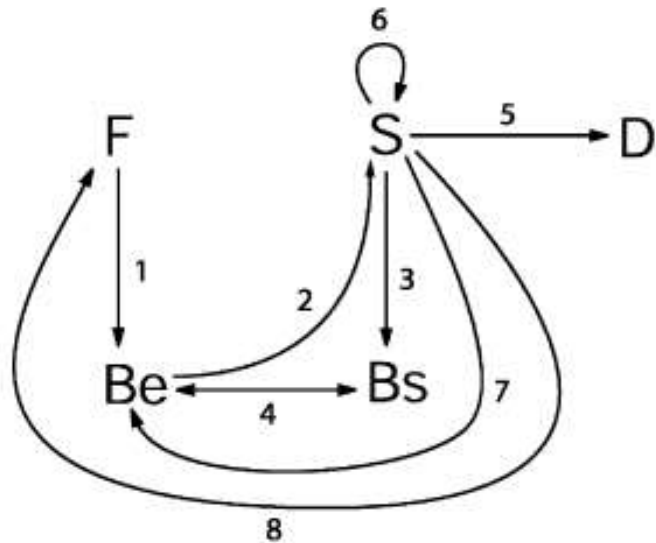
- Function (F): teleology of object (“what it is intended for”)
- Behavior (B): attributes derived or expected to be derived from structure (S) of object (“what it does” or “how it does it”)
- Structure (S): components of object and their relationships (“what it is composed of”)



Design Models

The FBS Ontology (Gero et al., 1990)

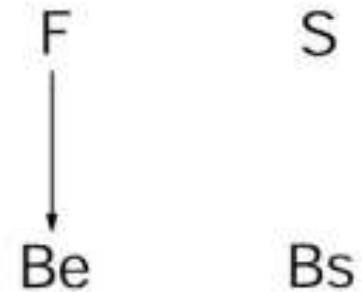
what are designers doing when they design



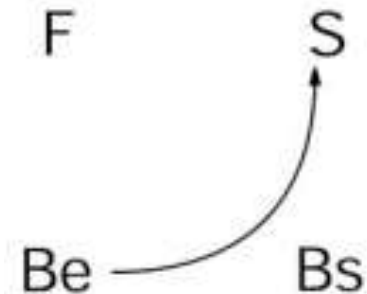
Be = expected behaviour
Bs = behaviour derived from structure
D = design description
F = function
S = structure

→ = transformation
↔ = comparison

1. Formulation



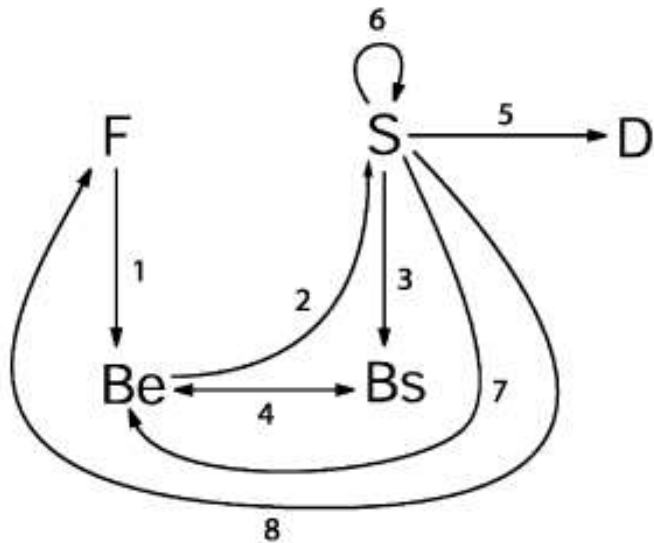
2. Synthesis



Design Models

The FBS Ontology (Gero et al., 1990)

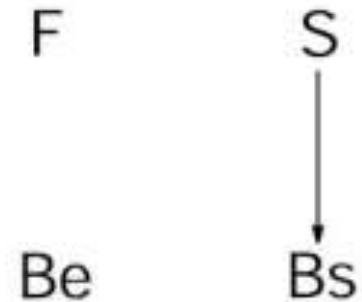
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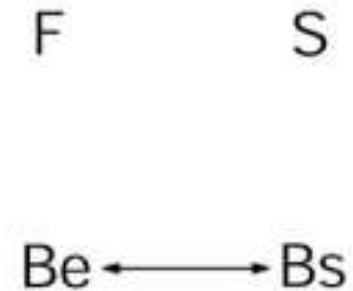
Be = expected behaviour
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3. Analysis



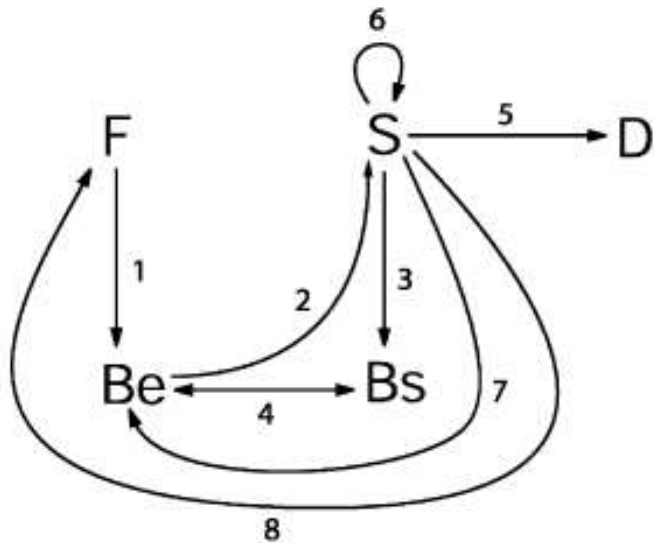
4. Evaluation



Design Models

The FBS Ontology (Gero et al., 1990)

what are designers doing when they design



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5. Documentation

F S → D

Be Bs

6. Reformulation 1

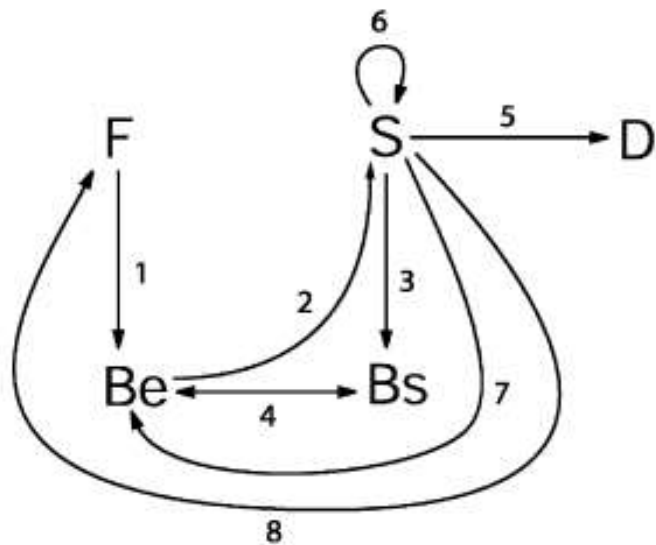
F S

Be Bs

Design Models

The FBS Ontology (Gero et al., 1990)

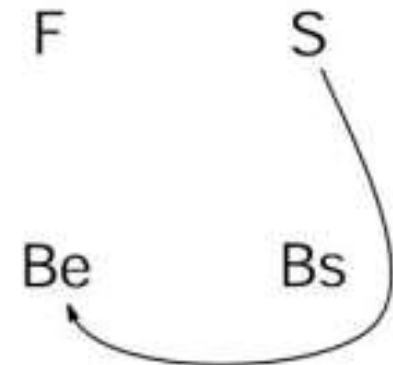
what are designers doing when they design



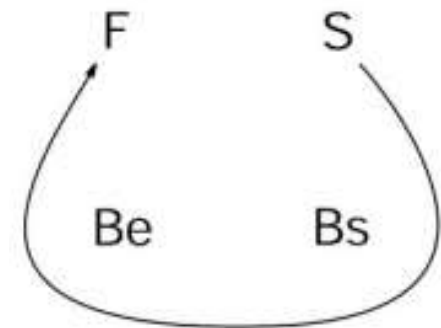
Be = expected behaviour
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↔ = comparison

7. Reformulation 2



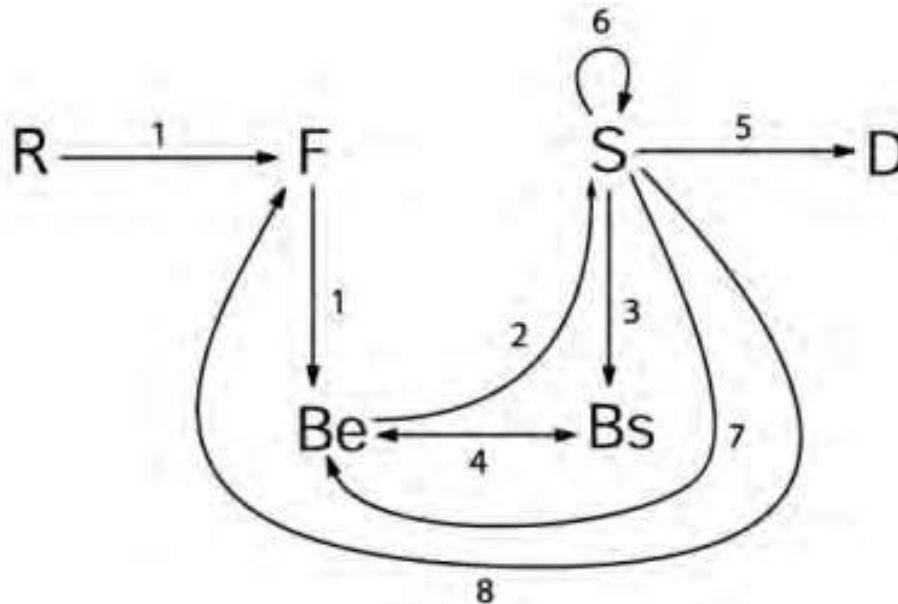
8. Reformulation 3



Design Models

The FBS Ontology (Gero et al., 1990)

what are designers doing when they design



F = function → = transformation
Be = expected behavior ↔ = comparison
Bs = behavior derived from structure
S = structure
D = design description

Processes in Designing

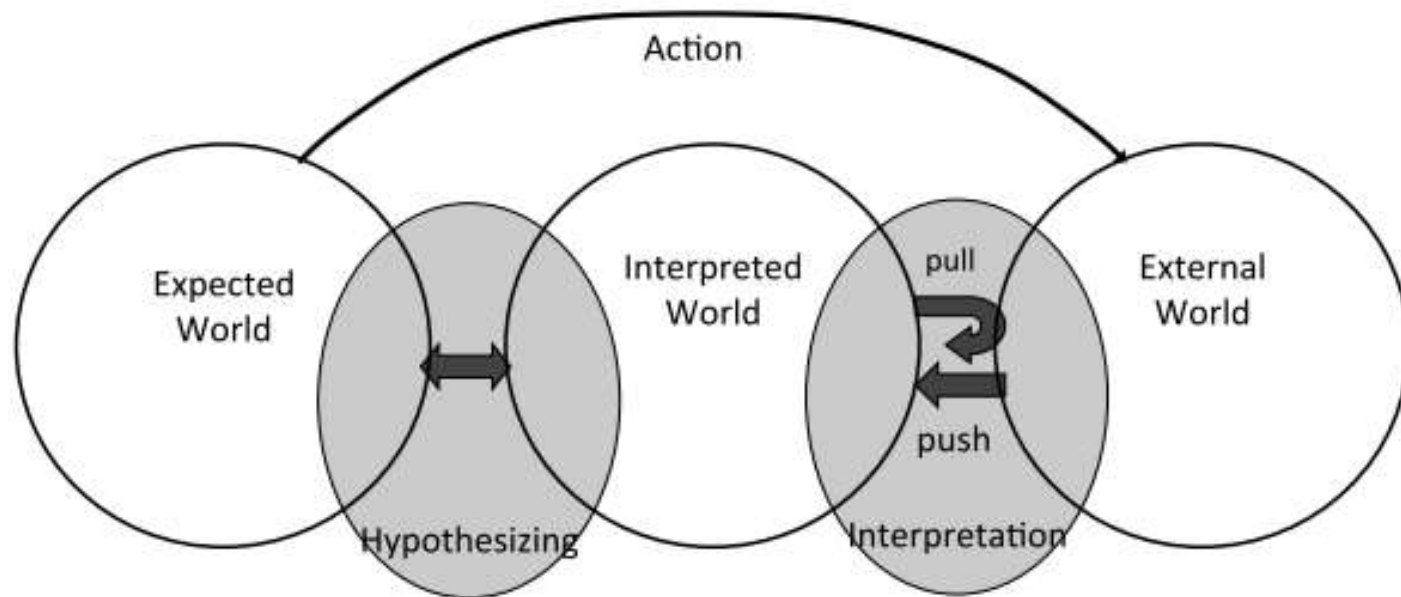
- 1 = formulation
- 2 = synthesis
- 3 = analysis
- 4 = evaluation
- 5 = documentation
- 6 = reformulation -1
- 7 = reformulation -2
- 8 = reformulation -3

Design Models

The FBS Ontology (Gero et al., 1990)

what are designers doing when they design

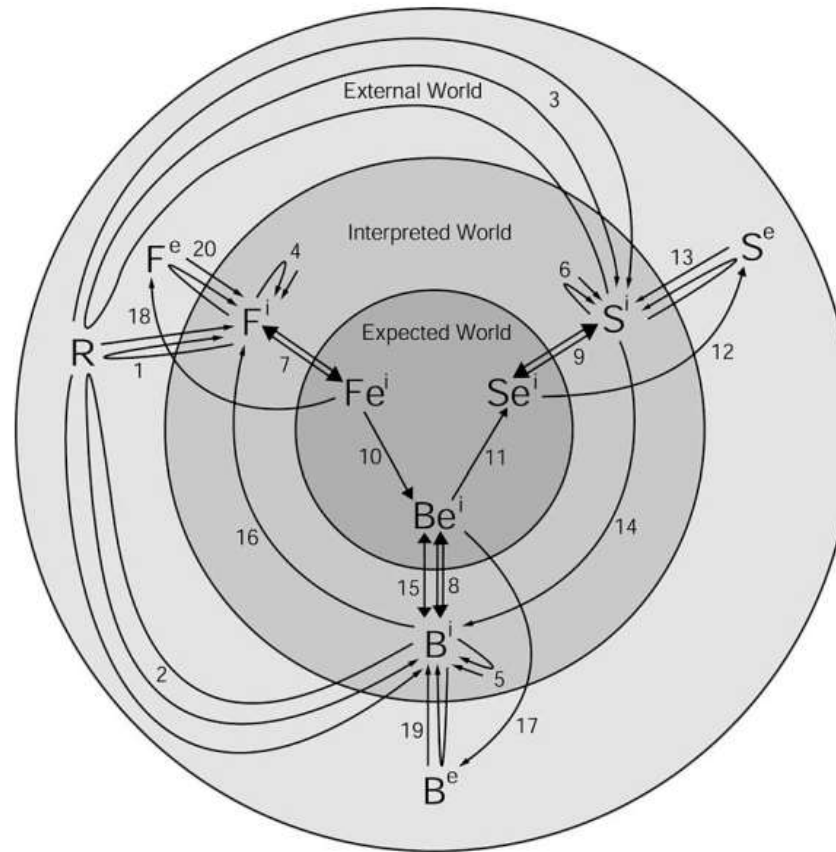
Design Cognition



Design Models

The FBS Ontology (Gero et al., 1990)

what are designers doing when they design

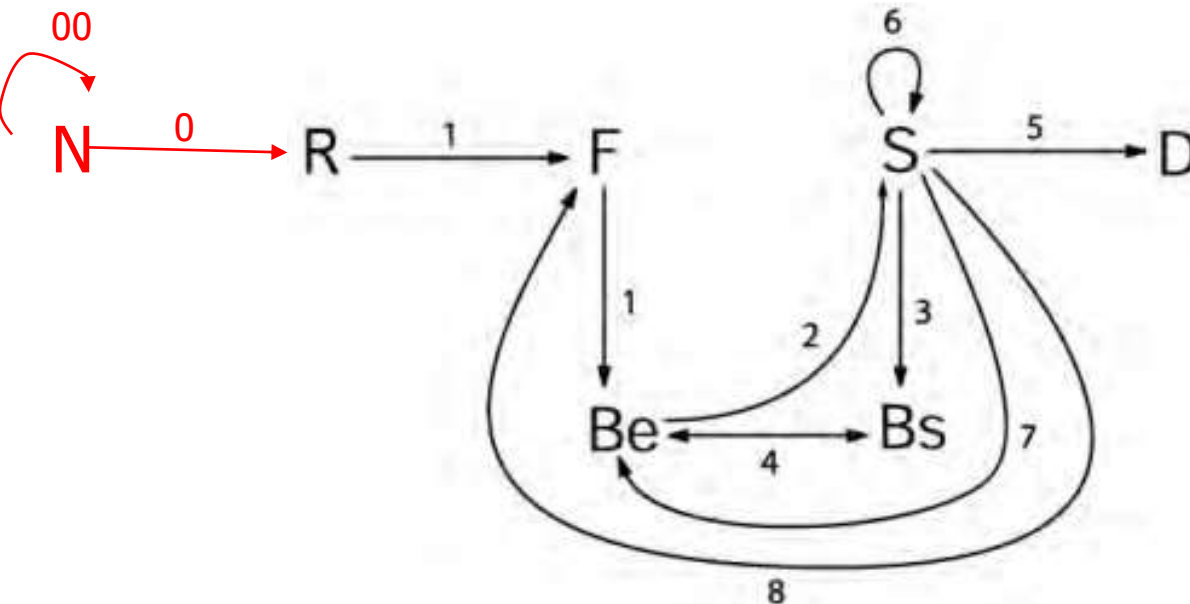


→ = transformation; ↔ = comparison; ↔ = focussing; ↺ = push-pull process

Design Models

The Extended FBS Ontology (Cascini et al., 2013)

what are designers doing when they design



F = function → = transformation
Be = expected behavior ↔ = comparison
Bs = behavior derived from structure
S = structure
D = design description

Processes in Designing

00 = NEEDS IDENTIFICATION
0 = REQUIREMENTS FORMUL.

1 = formulation

2 = synthesis

3 = analysis

4 = evaluation

5 = documentation

6 = reformulation -1

7 = reformulation -2

8 = reformulation -3

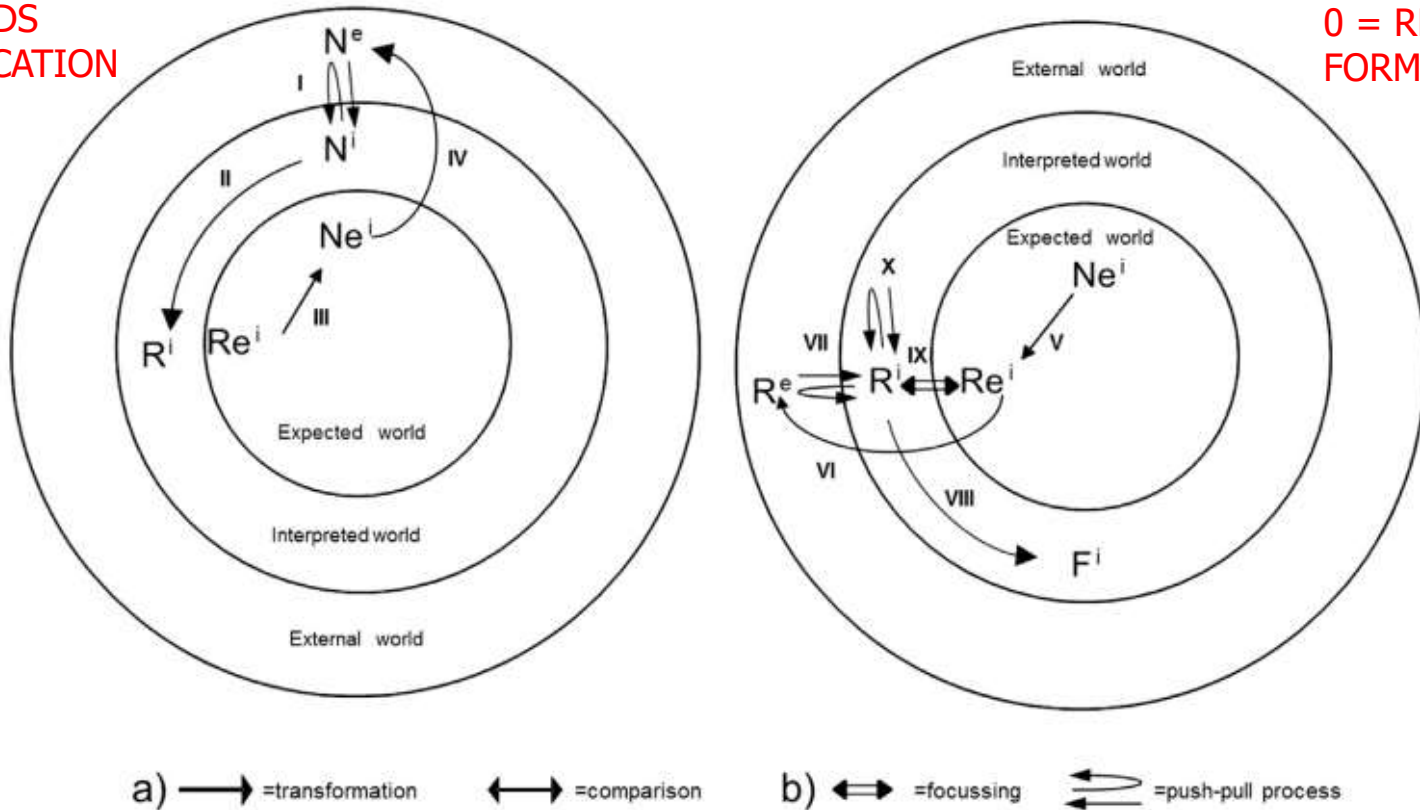
Design Models

The Extended FBS Ontology (Cascini et al., 2013)

what are designers doing when they design

00 = NEEDS
IDENTIFICATION

0 = REQUIREMENTS FORMUL.



2 Extended FBS model: Needs Identification (a) and Requirements Definition (b)

Design models

- Classification schemes
- Forms of reasoning
- FBS Design Ontology

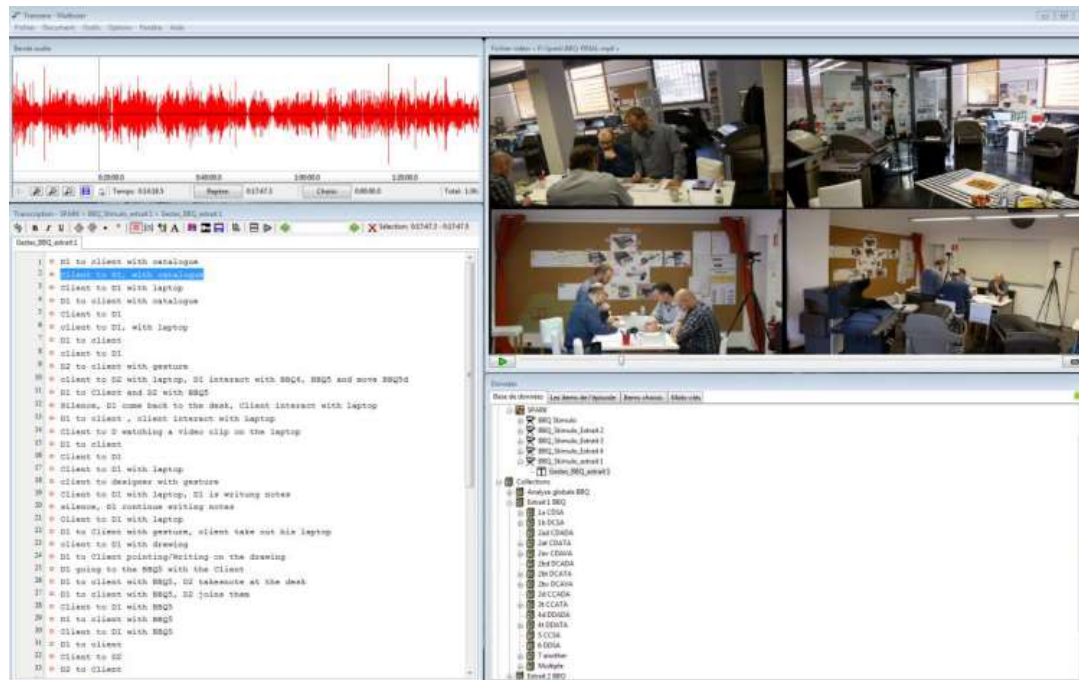
Observing design activities

- Design Protocol analyses
- Factors affecting design creativity

Observing Design Activities

Design Protocol Analyses

- segmentation of the analysis task into elementary steps
- analysis of the thinking path through a pre-defined coding



Observing Design Activities

Design Protocol Analyses (e.g., Gero et al, 2012)

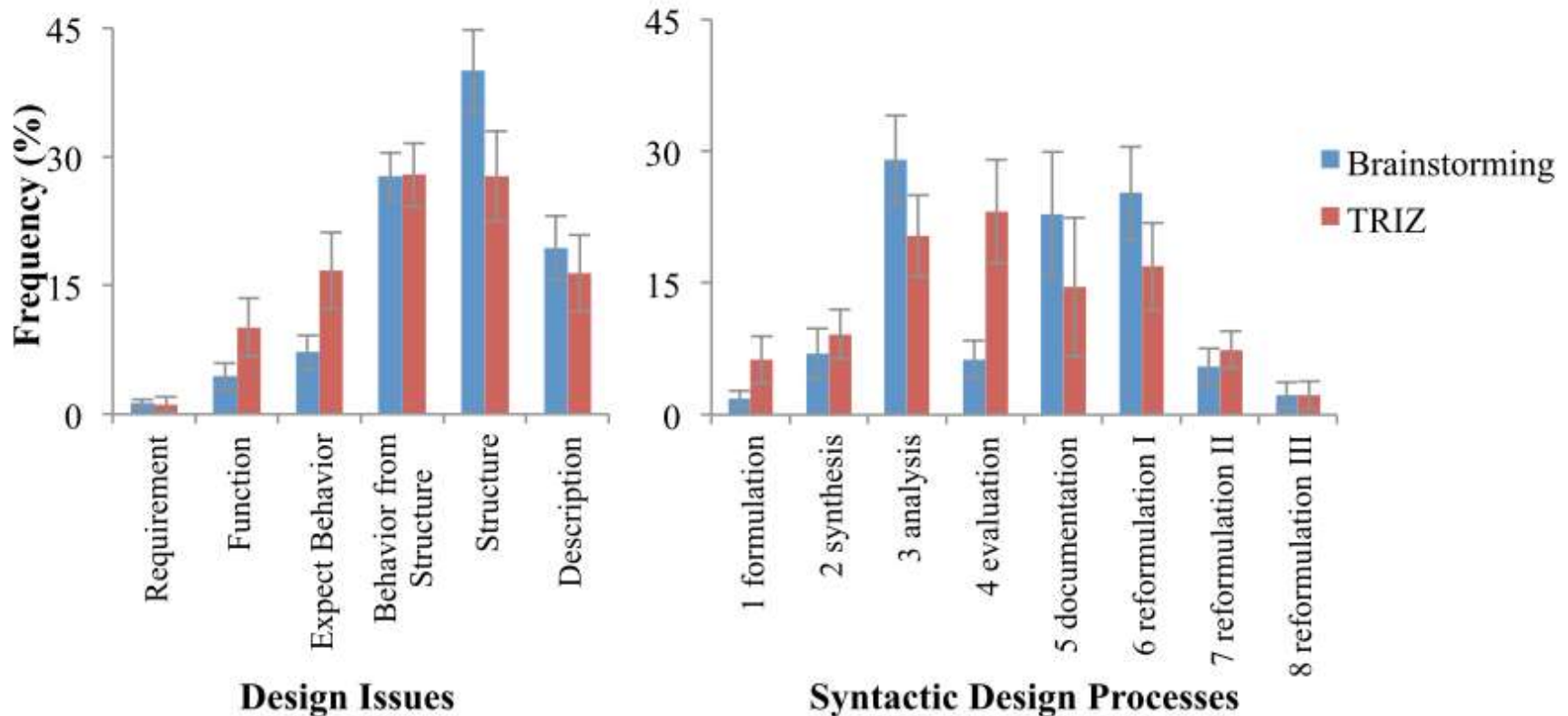
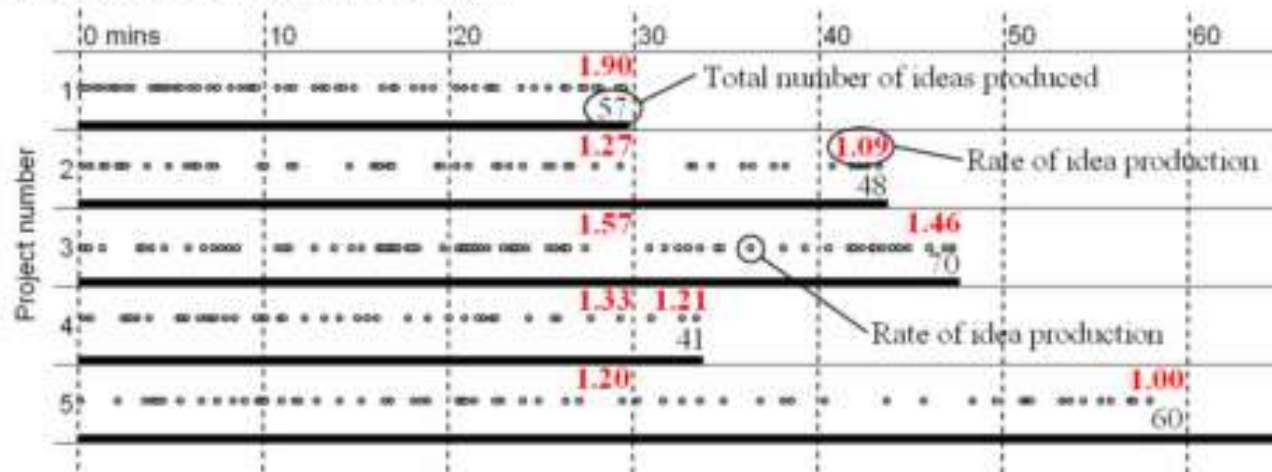


Figure 2. Frequency distribution of design issues and syntactic design processes (%)

Observing Design Activities

Design Protocol Analyses (e.g., Deckonink et al, 2012)

Our research on:
Creative Stimuli in Design



The **rate** of idea generation remained roughly constant for **30mins** and then decreased slowly and steadily.

The frequency of appropriate ideas was much more revealing. Over half of the **appropriate** ideas were produced in the first **10mins**.

The brainstorm sessions were deemed successful as 64% of original ideas contained within the **gate concepts** were proposed within the free thinking brainstorm session.

Observing Design Activities

Factors influencing design creativity

Memory and Remembering

“Remembering is not the re-excitation of innumerable fixed, lifeless and fragmentary traces. It is a ... reconstruction, or construction, built out of the relation of our *attitude* towards a whole active mass of organised past reactions or experience, and to a little outstanding detail which commonly appears in image or in language form.” Bartlett (1932)

Observing Design Activities

Factors influencing design creativity

Human Constructive Memory

- memory is reasoning process
 - index need not be explicit
 - index changed by its use
 - content changed by its use
 - memory structure changed by its use
-
- memories constructed through need to have memory
 - memories function of *past interactions* and *interactions at time and place* of need to have memory

Source: Gero (2016)

Observing Design Activities

Factors influencing design creativity

Interactions

- Interactions between people
- Interactions between person and artifact
- Interactions between artifacts
- Observing interactions between people
- Observing interactions between person and artifact
- Observing interactions between artifacts

Observing Design Activities

Factors influencing design creativity

Situated Cognition

Basic Ideas

Knowledge from interaction not just encoding

Memory by construction not just recall

Situations give meanings and expectations

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Thank you