From Computer-Aided Design to Computer-Aided Design **Creativity**

東京工業大学 機械物理工学専攻 メカノインフラデザイン分野

セリーヌ　ムージュノ

Céline Mougenot, PhD

Dijon mustard

Epoisses cheese

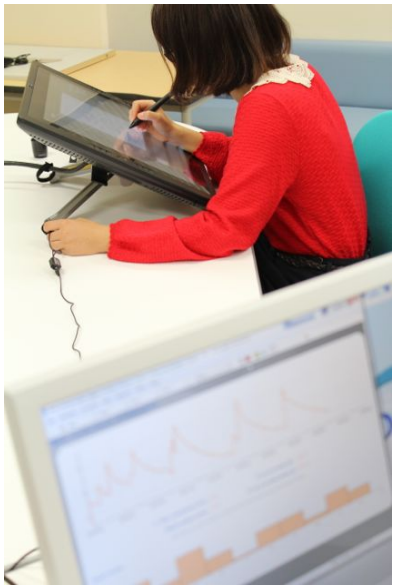
Bourgogne Wine

Background

Mixed background in mechanical engineering and industrial design

PhD Industrial Engineering (Design)
ENSAM (Arts et Metiers ParisTech), 2008

3D Design Engineering
Dassault Systèmes, 2001-2005



@ 東京工業大学 since 2011

メカノインフラデザイン分野
design lab

Outline

Design

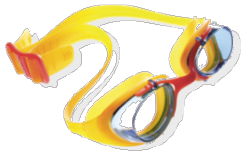
Design science

Design cognition

Perspective

Where is design ?

Products
Systems
Buildings
Spaces
Softwares
Processes
Data representation
Services
…



Worldwide interest in design

Design & Companies

Survey with 1,500 CEOs from 60 countries and 33 industries [IBM 2010 Global CEO Study]

> successfully navigating an increasing complex world will require creativity.

Design & Research

Major universities conduct design research within engineering departments (Stanford, MIT…)

New research initiatives focused on the study of designers practice : Design Thinking Research Symposium, NSF Workshop on Studying Designers…

Improving the artificial* world

* The Sciences of the Artificial (1996, 3rd ed.) Herbert A. Simon. MIT Press

Design is a creative activity whose aim is to establish the multi-faceted qualities of objects, processes, services and their systems in whole life-cycles.

Therefore, design is the central factor of **innovative humanization of technologies** and the crucial factor of cultural and economic exchange.

(International Council of Societies of Industrial Design)

Improving the artificial* world

* The Sciences of the Artificial (1996, 3rd ed.) Herbert A. Simon. MIT Press

innovative humanization of technologies

engineering

+

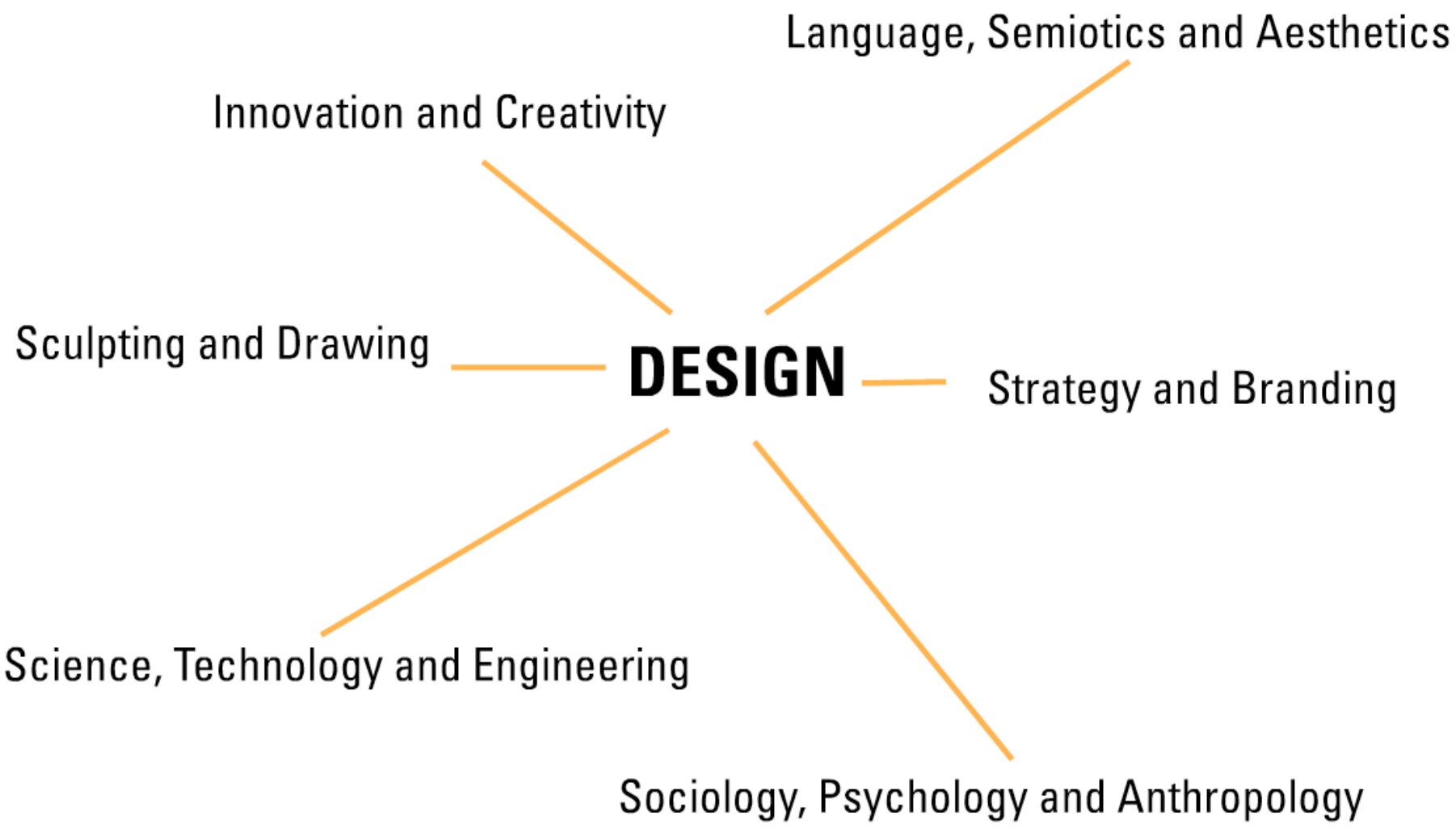
design

user-centered
and creative

=

happy users

Design is multidisciplinary



engineering

functions

design

functions

+

users

Form follows Function

「形態は機能に従う」

Louis Sullivan(American architect), 1896

Form follows Function

「形態は機能に従う」

Louis Sullivan(American architect), 1896

= The action for which a thing is particularly fitted or employed

form (style)

> another chair with a different shape / style

No innovation.

function

> an object that will keep a person in a seated position.

“Chairless” by Alejandro Aravena

Innovation !

Focus on "**what for ?**"

Design brief: "Design a chair"

↓

"What for ?" : to keep a person in a seated position.

↓

function ⟶ shape

What is the <u>function</u> of salt-and-pepper shakers ?

What is the function of salt-and-pepper shakers ?

To contain salt and pepper

What is the function of salt-and-pepper shakers ?

To contain salt and pepper
+ To indicate what is inside (salt or pepper)

only form = bad design

functions + form = good design

To contain salt and pepper
To indicate what is inside (salt or pepper)

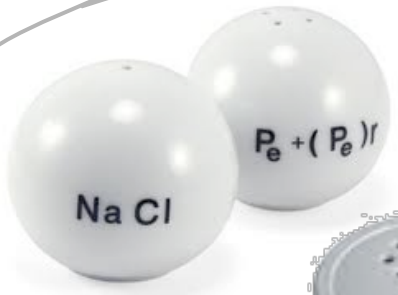
To contain salt and pepper
To indicate what is inside (salt or pepper)

same functions, various forms

FUNCTIONS
(1) To contain salt and pepper
(2) To indicate what is inside

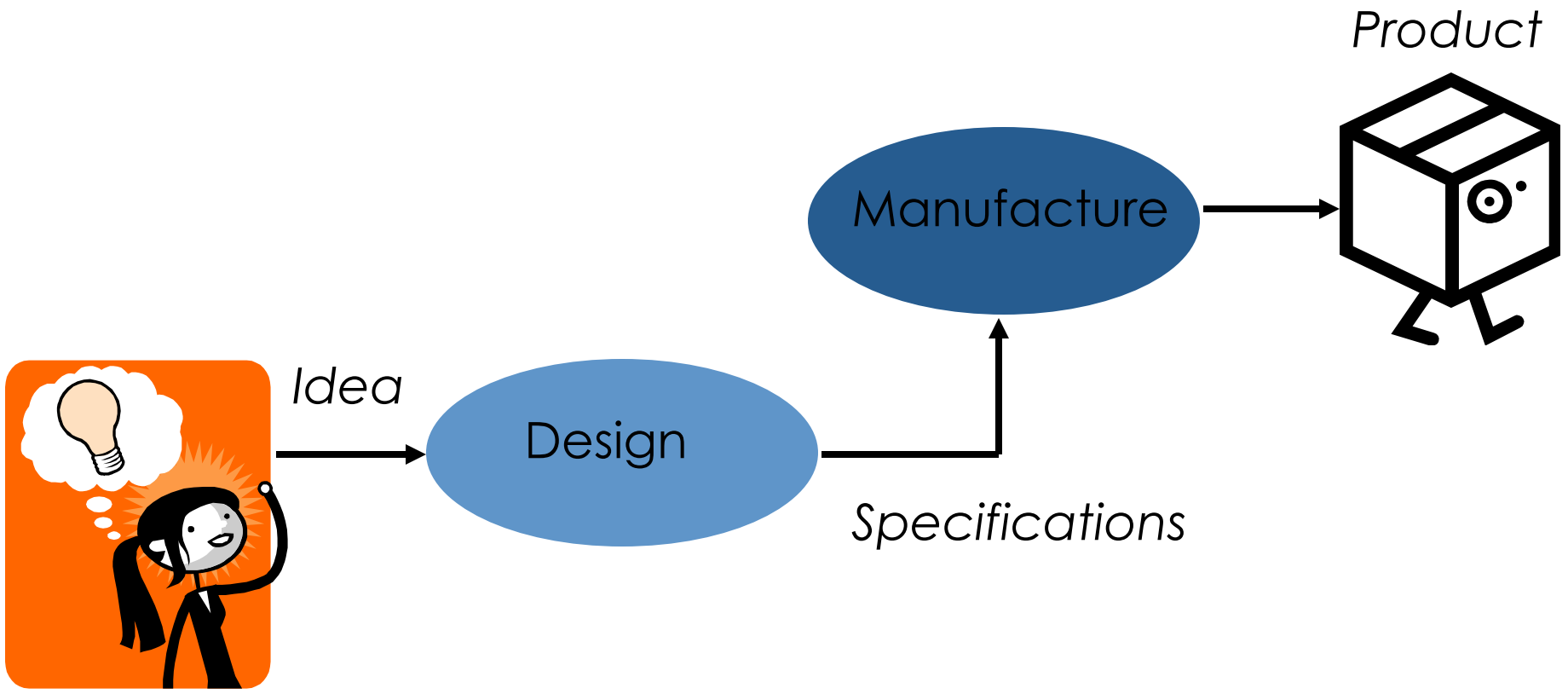
Transparent material

Shape / Color semantics



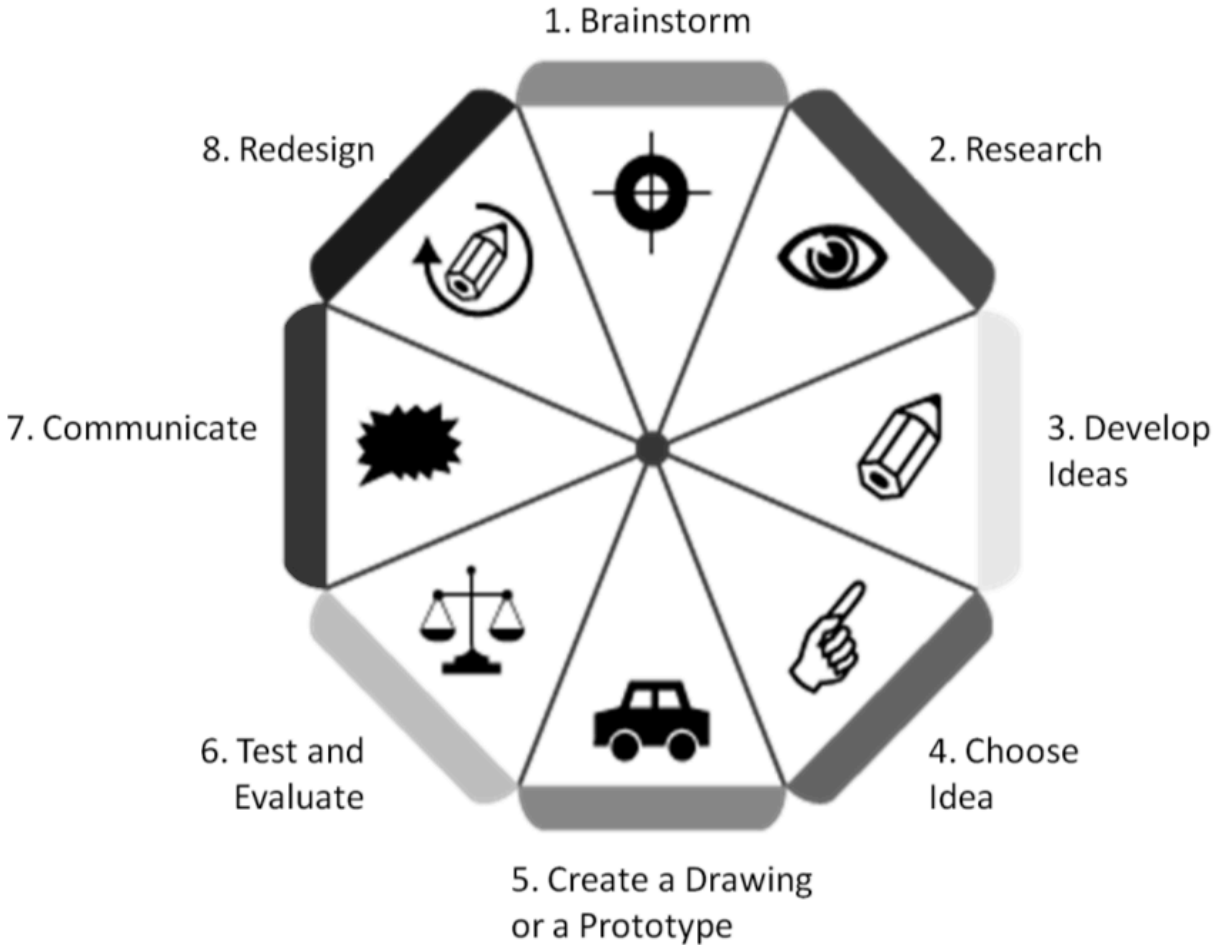
Verbal information

from a problem to a product



what steps ?

→ Several “models” of designing



Several views of the Design Process [Howard et al., 2008]

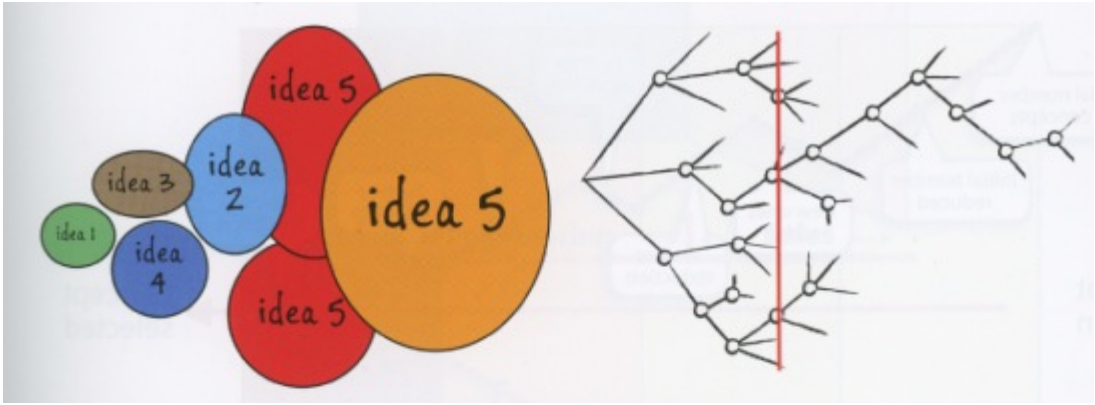
Models	Establishing needs	Analysis of task	Conceptual design	Embodiment design	Detailed design	Implementation
Booz et al. (1967)	X	New product strategy development	Idea generation | Screening & evaluation	Business analysis	Development | Testing	Commercialisation
Archer (1968)	X	Programming | data collection	Analysis | Synthesis	Development	Communication	X
Svensson (1974)	Need	X	Concepts | Verification | Decisions	X		Manufacture
Wilson (1980)	Societal need	Recognize & formalize | FR's & constraints	Ideate and create	Analyze and/or test	Product, prototype, process	X
Urban and Hauser (1980)	Opportunity identification	Design		Testing		Introduction (launch) | Life cycle management
VDI-2222 (1982)	X	Planning	Conceptual design	Embodiment design	Detail design	X
Hubka and Eder (1982)	X	X	Conceptual design	Lay-out design	Detail design	X
Crawford (1984)	X	Strategic planning	Concept generation	Pre-technical evaluation	Technical development	Commercialisation
Pahl and Beitz (1984)	Task	Clarification of task	Conceptual design	Embodiment design	Detailed design	X
French (1985)	Need	Analysis of problem	Conceptual design	Embodiment of schemes	Detailing	X
Ray (1985)	Recognise problem	Exploration of problem | Define problem	Search for alternative proposals	Predict outcome | Test for feasible alternatives	Judge feasible alternatives | Specify solution	Implement
Cooper (1986)	Ideation	Preliminary investigation	Detailed investigation	Development | Testing & Validation	X	Full production & market launch
Andreasen and Hein (1987)	Recognition of need	Investigation of need	Product principle	Product design	Production preparation	Execution
Pugh (1991)	Market	Specification	Concept design		Detail design	Manufacture | Sell
Hales (1993)	Idea, need, proposal, brief	Task clarification	Conceptual design	Embodiment design	Detail design	X
Baxter (1995)	Assess innovation opportunity	Possible products	Possible concepts	Possible embodiments	Possible details	New product
Ulrich and Eppinger (1995)	X	Strategic planning	Concept development	System-level design	Detail design	Testing & refinement | Production ramp-up
Ullman (1997)	Identify needs | Plan for the design process	Develop engineering specifications	Develop concept	Develop product		X
BS7000 (1997)	Concept | Feasibility		Implementation (or realisation)			Termination
Black (1999)	Brief/concept	Review of 'state of the art'	Synthesis | Inspiration	Experimentation | Analysis / reflect	Synthesis | Decisions to constraints | Output	X
Cross (2000)	X	Exploration	Generation	Evaluation	Communication	X
Design Council (2006)	Discover	Define	Develop	Deliver		X
Industrial Innovation Process 2006	Mission statement	Market research	Ideas phase	Concept phase	Feasibility Phase	Pre production

design creativity / idea generation

Creating user experiences: aesthetically pleasing, supportive of creativity, rewarding, emotionally fulfilling, fun, satisfying, enjoyable, entertaining, helpful, motivating, supporting human relationships etc.

finding design concepts

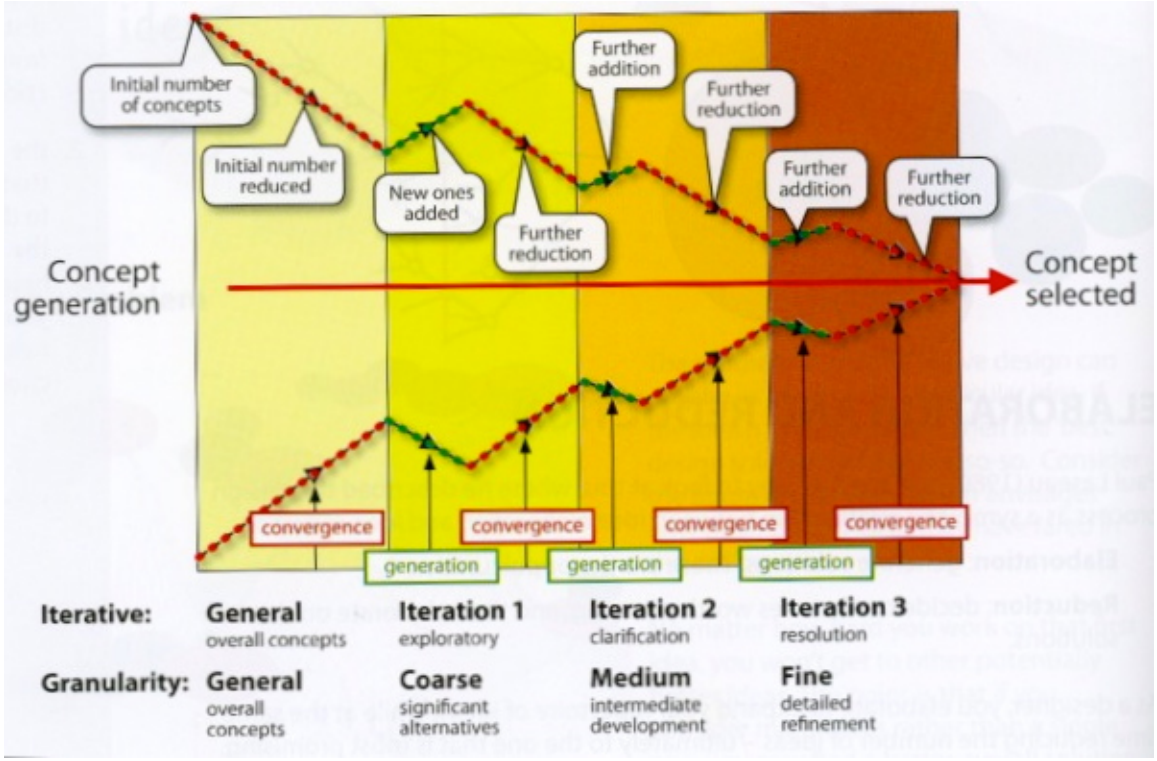
Considering many other ideas an then choosing from them
= generating multiple solutions simultaneously



finding design concepts

Convergence of ideas

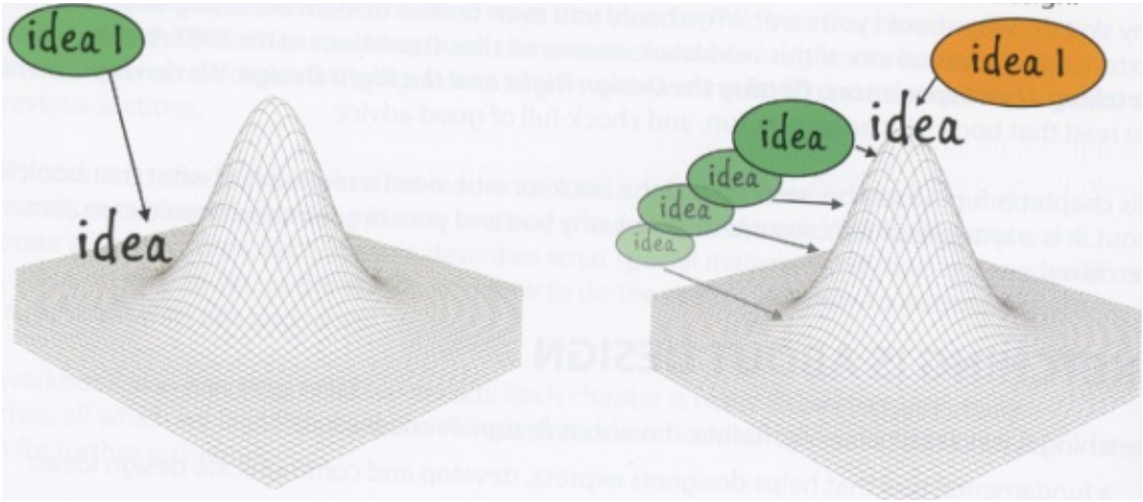
- Each stage is iterative (generation and reduction of ideas)
- Level of development (granularity) is finer as iterations progress.



Pugh S. (1990) Total Design: Integrated Methods for Successful Products Engineering. Ed. Addison-Wesley.

Finding GOOD design concepts

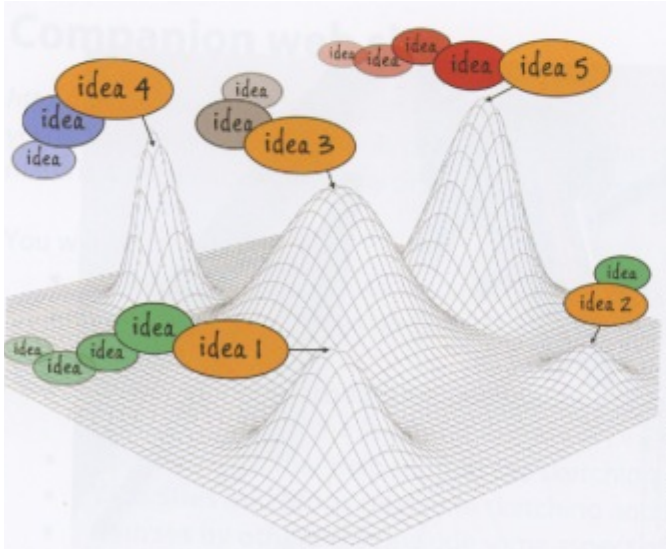
Start from an initial idea, develop until solution.



Finding GOOD design concepts

BUT
if **initial idea** is not a good one, final solution will be so-so.

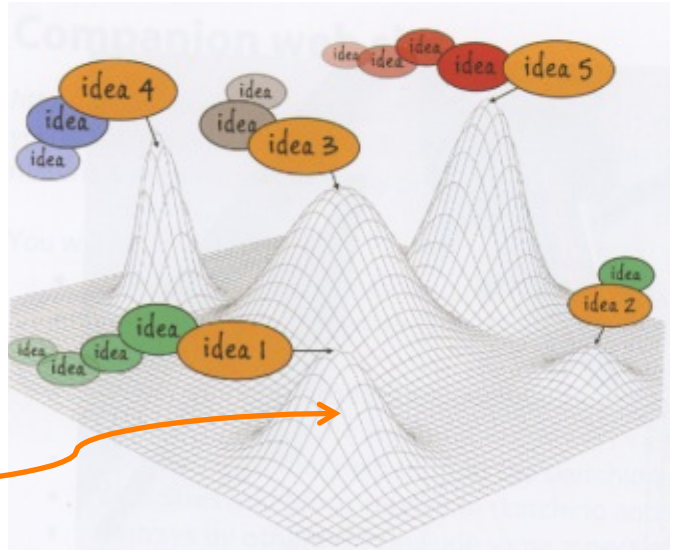
"local hill climbing": local maxima is potentially much less than global maxima.



Finding GOOD design concepts

BUT
if **initial idea** is not a good one, final solution will be so-so.

"local hill climbing": local maxima is potentially much less than global maxima.

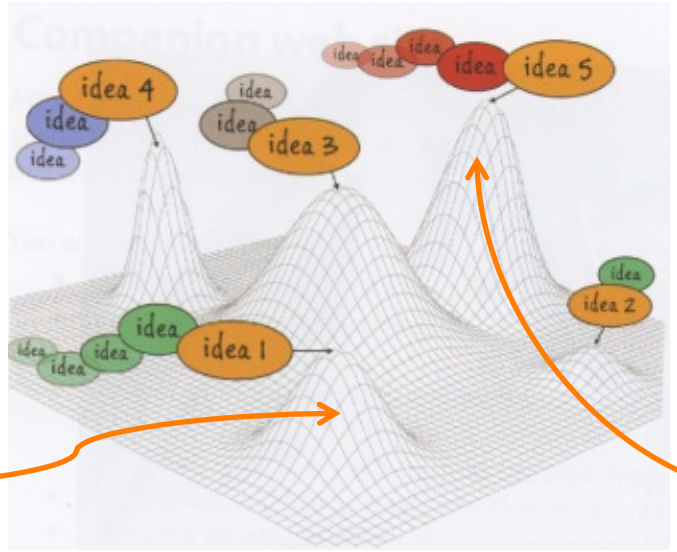


From 1980's:
cell phones with
keyboard and screen

Finding GOOD design concepts

BUT
if **initial idea** is not a good one, final solution will be so-so.

"local hill climbing": local maxima is potentially much less than global maxima.



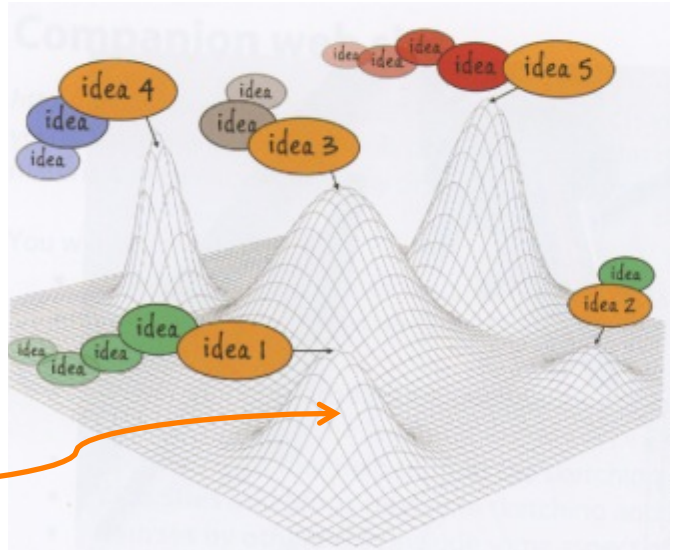
From 1980's:
cell phones with
keyboard and screen

From 2000's:
touch display
and no keyboard

Finding GOOD design concepts

BUT
if **initial idea** is not a good one, final solution will be so-so.

"local hill climbing": local maxima is potentially much less than global maxima.



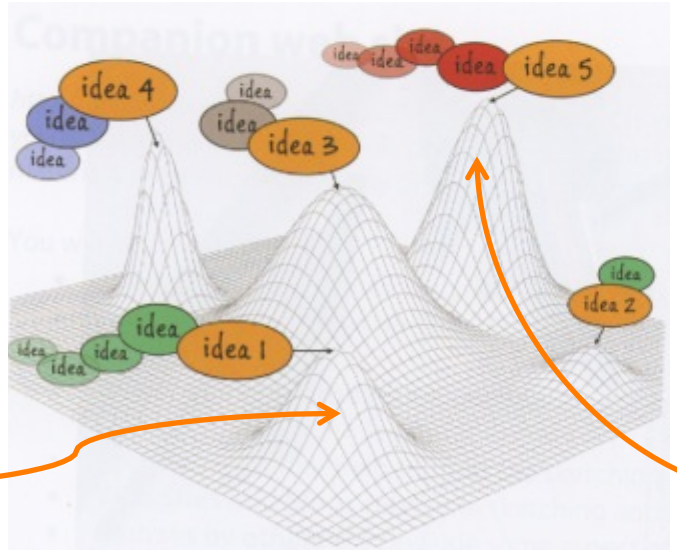
Traditional alarm clock:
Noisy alarm

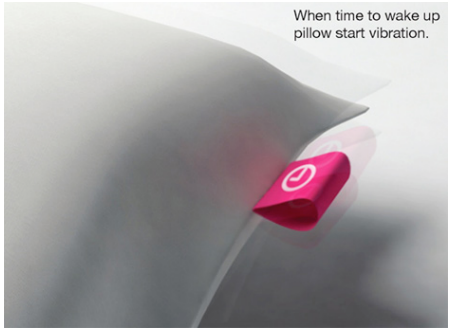
Finding GOOD design concepts

BUT
if **initial idea** is not a good one, final solution will be so-so.

"local hill climbing": local maxima is potentially much less than global maxima.

Traditional alarm clock:
Noisy alarm





Alternative waking-up system:
Vibrations

Design science

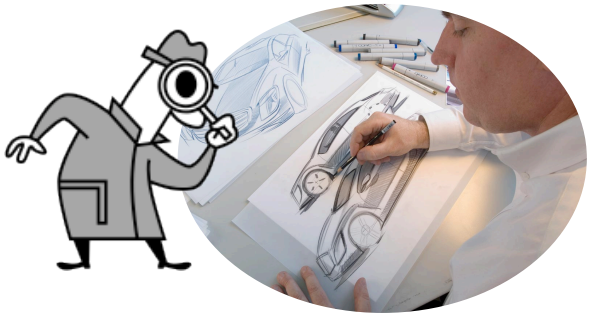
Scientific studies of :

- human-product relationship > focus on **user**

  e.g The effect of product on users' cognition and emotion
  How to improve the user-friendliness of products

- design process, design cognition > focus on **designer**

  e.g How designers make analogies when solving design problems
  How visual sources of inspiration influence creativity



Scientific community

- Journals: Design Studies, Design Issues, JDR…
- Conferences: IASDR, DESIGN, DRS, ICDC, DCC…
- Scientific societies: Design Society, Design Research Society…

Recently:

Major universities conduct design research (Stanford, MIT…)

New research initiatives are launched: Design Thinking Research Symposium (2005~), NSF Workshop on Studying Designers (2008~)…

Cognitive view of designing process

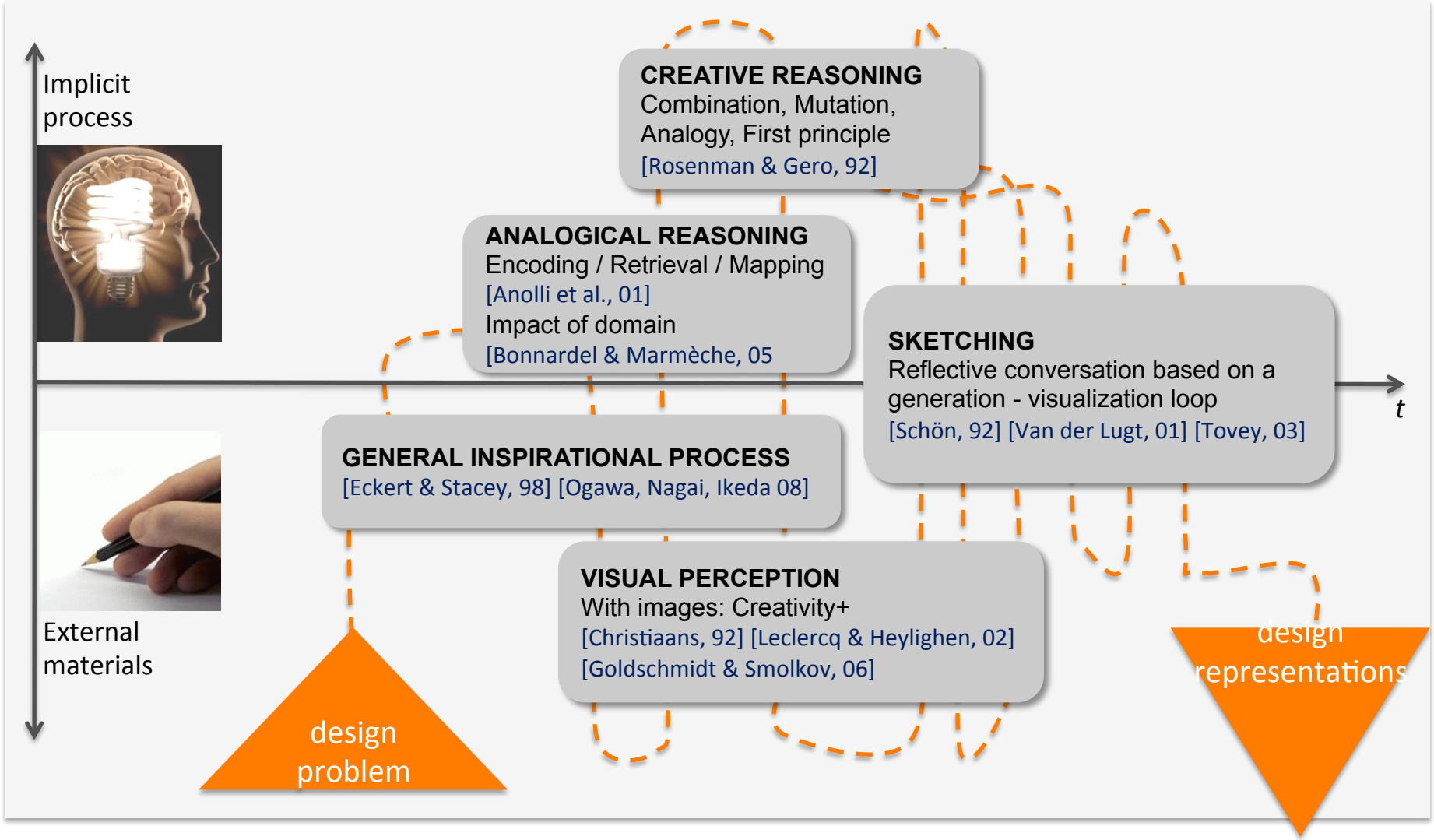
Designing: Solving an ill-defined problem with has an infinite number of possible solutions

≠ problem-solving (1 solution)

- Mental operations to generate and to evaluate ideas.

- Generation of external representations (e.g. sketches)

Cognitive view of designing process



Generation of external representations (Sketching)

Sketching as a support to the cognitive process of designing :

- Reflective conversation of designer with him/herself [Schön, 92]
  "seeing – drawing – seeing"
- "Generation – Visualization – Evaluation" loop [Van der Lugt, 01] [Tovey, 03]

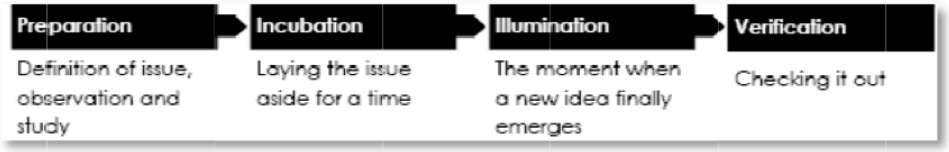
Sketching allows to:

- Externalize and visualize design problems
  > support to **memory**

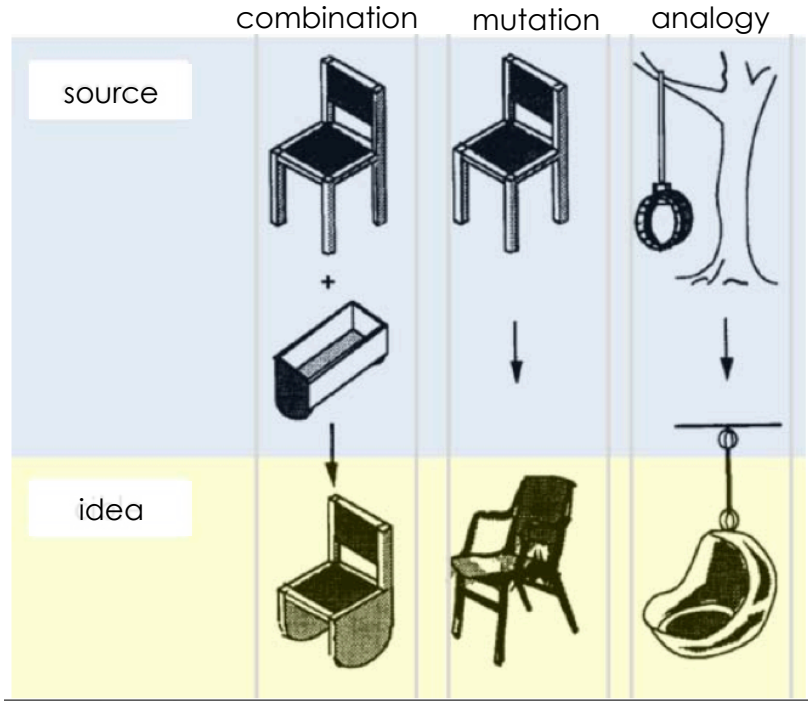
- Facilitate the perception and interpretation of ideas
  > support to **analogical reasoning**

Creative reasoning

Illumination model [Wallas, 1926]



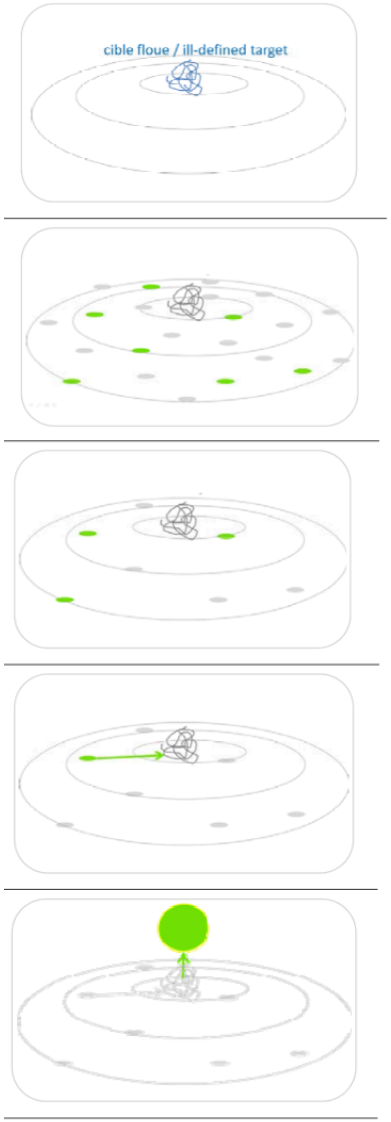
From [Rosenman & Gero, 1992]



Creative reasoning

→ Mechanism of analogical reasoning

Analogical reasoning is composed of the following stages [Anolli et al., 2001] :



- **Encoding: perception of external sources**

- **Retrieval: identification of useful sources**

Retrieval	(Holyoak & Koh, 1987; Keane, 1985, 1987; Novick & Holyoak, 1991)
Search	(Hesse, 1991)
Selection	(Clement & Gentner, 1991; Gentner & Toupin, 1986; Holyoak & Koh, 1987; Holyoak & Thagard, 1989)
Access	(Ross, 1987; Ross & Kennedy, 1990; Schunn & Dunbar, 1996).

- **Mapping: extraction of useful aspects for solving the target problem**

Mapping	(Clement & Gentner, 1991; Gentner & Toupin, 1986; Holyoak & Koh, 1987; Holyoak & Thagard, 1989; Novick & Holyoak, 1991)
Use	(Schunn & Dunbar, 1996)
Applying	(Gick & Holyoak, 1983; Gick & McGarry, 1992; Ross, 1987, 1989)
Adapting	(Keane, 1996; Novick & Holyoak, 1991).

- **Emergence: formulation of a solution to the target problem thanks to the source**

Analogical reasoning

→ Domains of sources of inspiration

[Bonnardel et al., 2005]

Ex. : design of a new café seat

A source of inspiration is judged as :

- **intra-domain** if, without any ambiguity, it pertains to the category, which the object to be designed belongs to.
- **close inter-domain** if it keeps some properties of the target-object category but not the most prototypical ones.
- **far interdomain** if it obviously does not belong to the category of the target object.

Intra-domain

Close inter-domain

Far inter-domain

- Evocation of useful aspects for design:
  - FUNCTIONAL
  - STRUCTURAL
  - ASTHETICAL
  - AFFECTIVE

- Correlation between source domain and type of evoked aspects :

  e.g.: "when participants were provided with **far inter-domain** sources, they mainly expressed **affective** aspects"

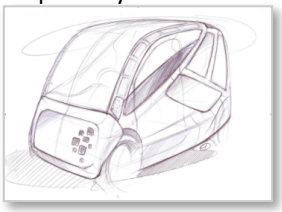
Analogical reasoning

→ Domains of sources of inspiration

[Mougenot et al., 2008]

e.g.visual stimulus from architecture

→ sketched concept inspired by architecture



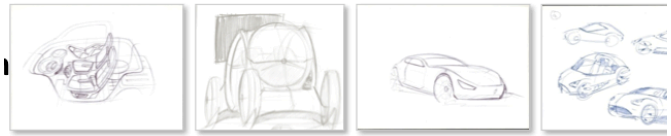
Task: Designing a new concept car based on a brief
Method: Sketches assessment of novelty and feasibility by external judges (3)

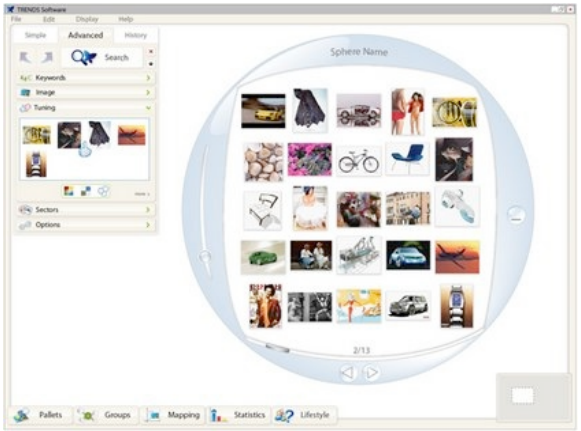
Sketches of cars inspired by images of:

cars

architecture

fashion





Creativity evaluation (assessment of novelty and feasibility by external judges)

- The level of **novelty** increases with the distance between source and target.
- The level of **feasability** tends to be optimum with intra-domain sources.

→ **Visual stimulation from other sectors enhances design creativity.**

REFERENCES

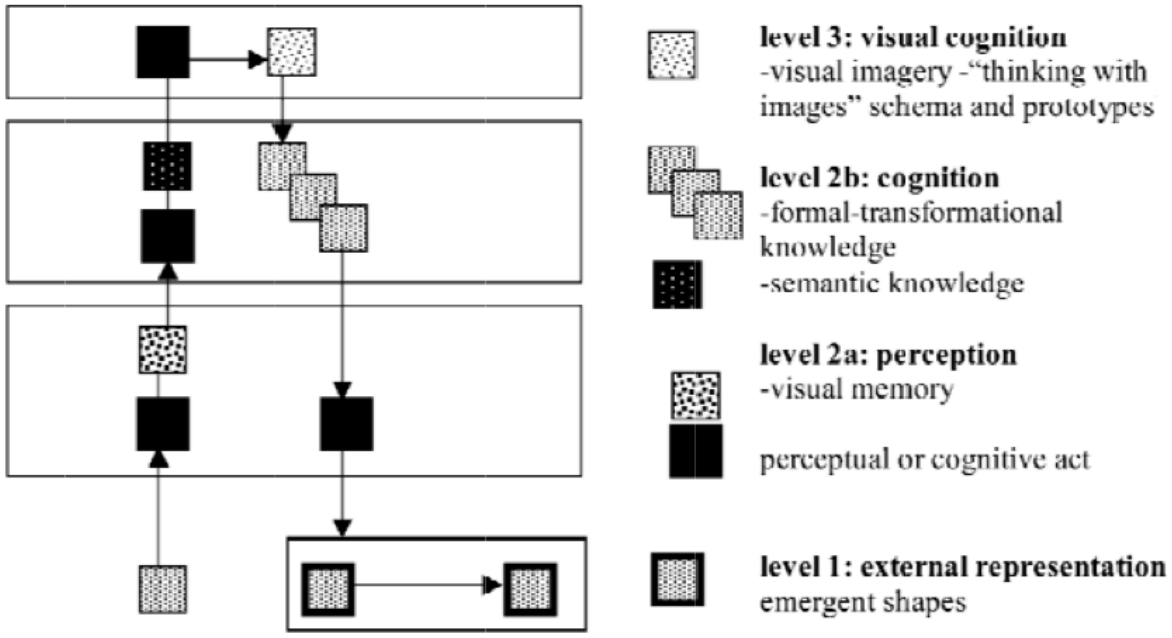
Bouchard C., Omhover J.F., Mougenot C., Aoussat A., Westerman S.J. (2008) TRENDS: A Content-based Information Retrieval System for Designers. Design Computing and Cognition '08. pp 593-611. Ed.: J.Gero, A.Goel. Springer. ISBN-13: 978-1402087271

Mougenot C., Bouchard C., Aoussat A., Westerman S.J. (2008) Inspiration, Images and Design: An Investigation of Designers' Information Gathering Strategies. Journal of Design Research, 7(4):331-351

Analogical reasoning
→ The role of images

Visual information support analogical reasoning.

Emergence mechanism [Oxman, 2002]:
Visual stimulus → Mental imagery → Solution



Analogical reasoning
→ The role of images

Visual stimuli favor creativity by analogical reasoning [Malaga, 2000]

word → creativity +
word + image → creativity +++
image → creativity +++++

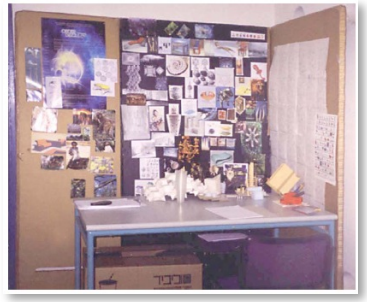
Comparing 2 design conditions: with / without visual stimuli

Under visual stimulation:

- The quantity of ideas is increased
[Christiaans, 1992]

- The level of creativity (originality and feasibility) is improved
[Goldschmidt & Smolkov, 2006]


No visual stimuli

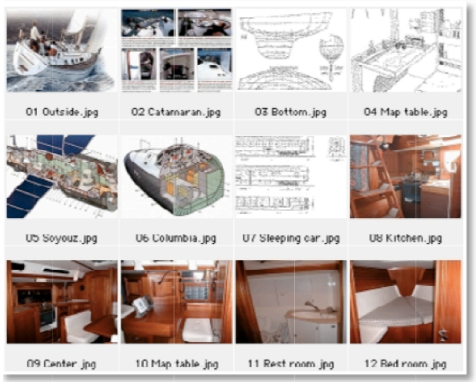

With visual stimuli

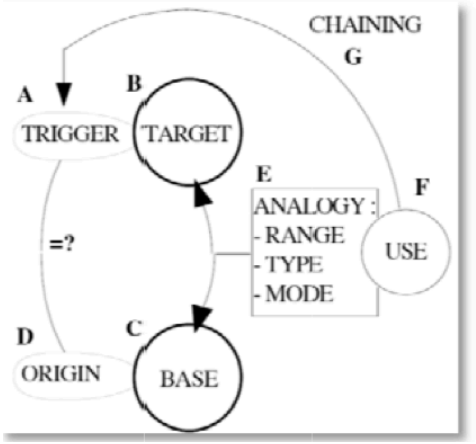
Analogical reasoning
→ process in design situation

Protocol analysis with architectural designers [Leclercq & Heylighen, 2002]

Design task: designing the main room of a boat
Sources of inspiration: pictures of main room of boats, boat devices, landscapes…
Method: Think-aloud observations + Interviews + Sketch analysis
Coding of analogies:

- Range (direct / undirect link between source and target)
- Type (spontaneous / forced analogy)
- Mode (conscious / unconscious analogy)



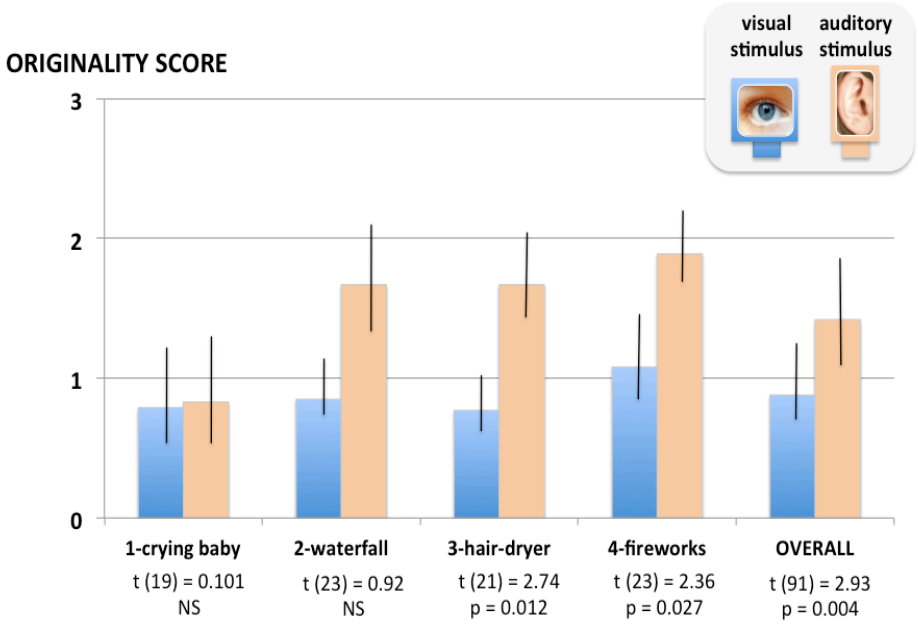


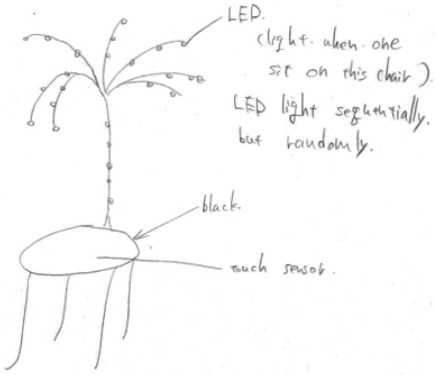
RESULTS
3 participants, 144 analogies, 5,8 analogies / hour / designer
75% lead to ideas that are kept towards the final solution.
70% are spontaneous (not forced by designer).
66% come from details of an image, not the entire picture.
43% come from external sources, not designers' own memory.

Images vs. Sounds

→ effects of visual and auditory stimuli in a design situation

Task: designing a novel type of chair
Sources of inspiration: images and sounds
Method: sketch assessment by external judges (2)





Source of inspiration:
Image of fireworks

Source of inspiration:
Sound of fireworks

- Higher originality scores in auditory condition.
- Auditory condition: designers tend to recall memories.
- Visual condition: designers tend to reproduce what they see.

→ **Visual stimulation provokes design fixation, while auditory stimulation support originality.**

REFERENCE
Mougenot C., Watanabe K. (2012) Studying Designers: Affective components of design creativity. Design Creativity 2012 (Poster).

Neurological basis of design cognition

fMRI study with designers [Alexiou et al., 2009. Design Studies]

Task: think of a furniture layout in a room
- in a fully-constrained way (problem-solving taks)
- in a ill- defined way (design task).

Method: fMRI recording brain activity

FINDING: "Design" and "problem solving" involve distinct cognitive functions associated with distinct brain networks.

•brain processing in design is different from brain processing in problem-solving

Neural network involved in artistic activity [Kowatari et al., 2009. Human Brain Mapping]

Task: designing a new pen.

Method: fMRI recording brain activity + originality scores given to the design outputs + novices vs. expert comparison.

FINDING: training increases creativity through a reorganization of intercortical interactions.

• training and expertise in design impact brain processing and increase creativity

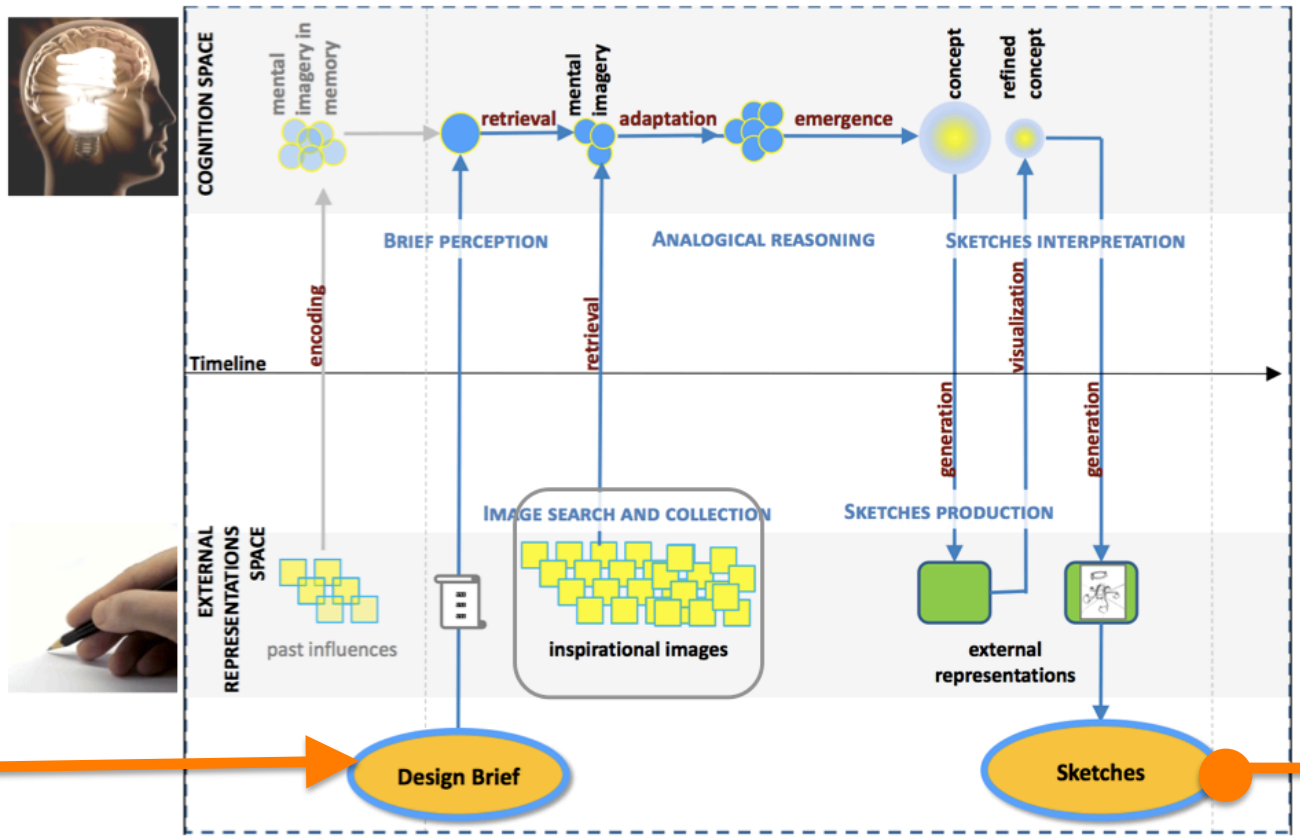
DESIGN INFORMATIONAL PROCESS

EXTERNAL INFORMATION

- Design brief
- Images
- Patents

PRODUCT REPRESENTATION

- Sketches
- CAD Models
- Prototypes
- Manufactured product



DESIGN INFORMATIONAL PROCESS

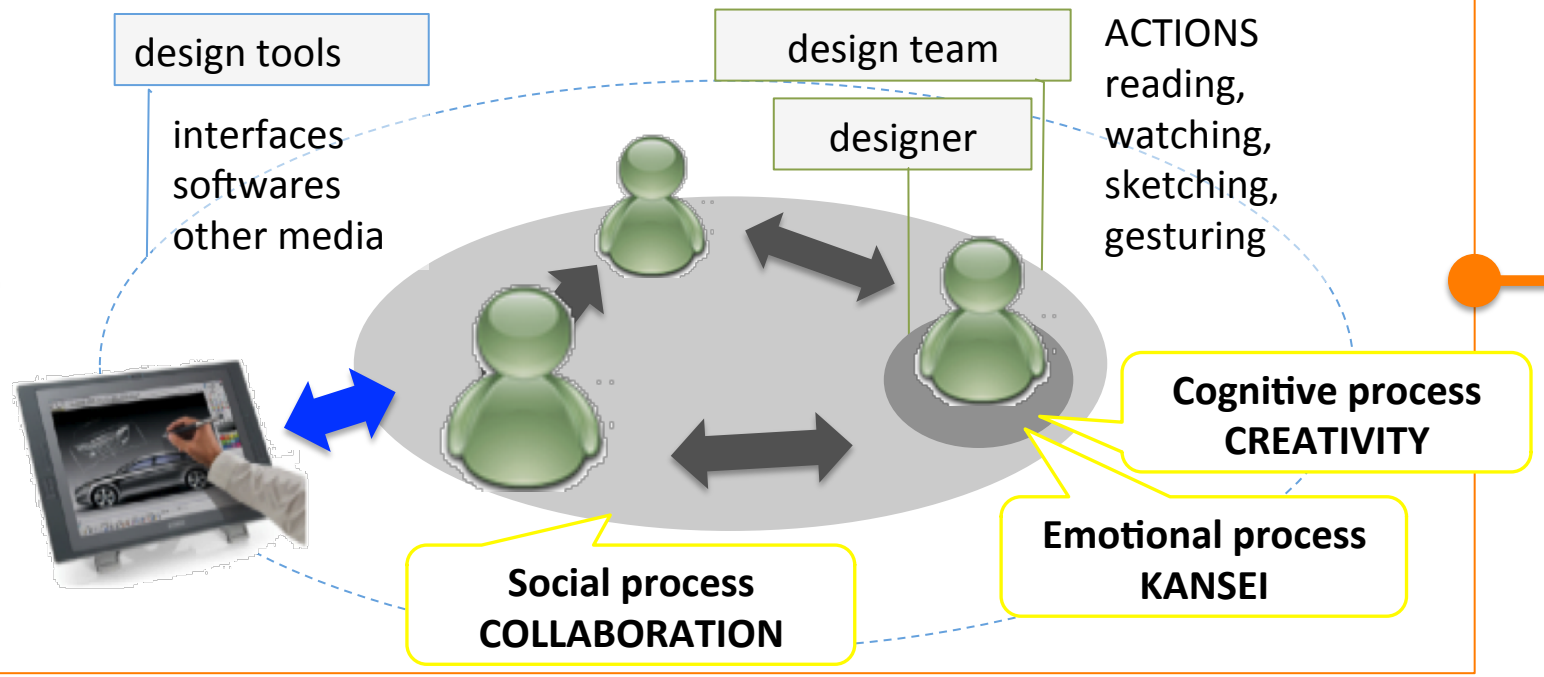
EXTERNAL INFORMATION

- Design brief
- Images
- Patents

PRODUCT REPRESENTATION

- Sketches
- CAD Models
- Prototypes
- Manufactured product

DESIGNING ACTIVITY



RESEARCH FOCUS

CREATIVITY	> Design cognitive process
KANSEI	> Design emotional process
COLLABORATION	> Design social process

RESEARCH DATA COLLECTION

- General activity recording (video, motion capture)
- Visual activity recording (eyes-tracking)
- Psycho-physical data recording (GSR)

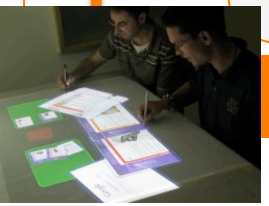
DESIGN INFORMATIONAL PROCESS

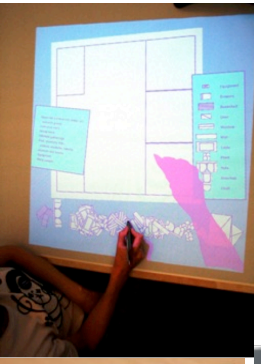
EXTERNAL INFORMATION

- Design brief
- Images
- Patents

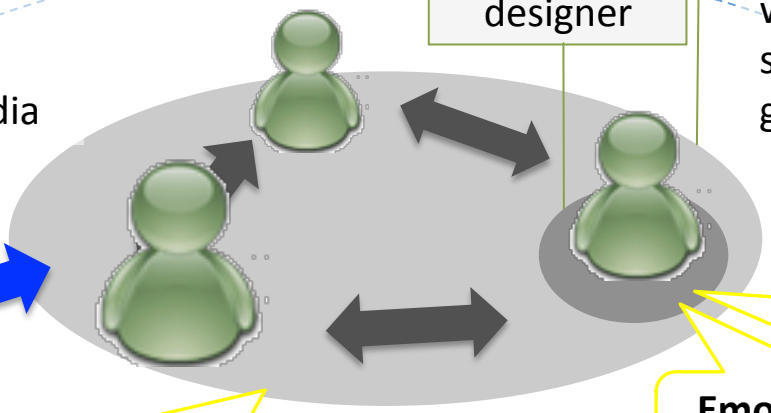
PRODUCT REPRESENTATION

- Sketches
- CAD Models
- Prototypes
- Manufactured product





DESIGNING ACTIVITY



RESEARCH FOCUS

CREATIVITY	> Design cognitive process
KANSEI	> Design emotional process
COLLABORATION	> Design social process

RESEARCH DATA COLLECTION

- General activity recording (video, motion capture)
- Visual activity recording (eyes-tracking)
- Psycho-physical data recording (GSR)

Thank you for listening

mougenot@mech.titech.ac.jp