

### Introduction

Design is understood as an ill-defined process, hence no clear operators are defined. Therefore, understanding reasoning in design activity is fundamental for building AI or other design support tools. Design is intentional, purposive and goal-seeking and involves many forms of mental activity, relying on reasoning processes both in individuals and groups. Therefore, studying the role reasoning plays in design is critical to understand how design takes place (Rittel 1987).

Roozenburg's (1993) model for reasoning in design, proposes that innovative abductive reasoning is key in design and required to develop innovative ideas. Four types of reasoning are proposed (Roozenburg, 1993):

- Deductive reasoning is the inference of a result from a rule and a case
- Inductive reasoning is the inference of a rule from a case and a result
- Explanatory abductive reasoning is the inference of a case from a rule and a result
- Innovative abductive reasoning is the inference of a (new) rule and case from a result

Below, the four types of reasoning are presented in propositional logic:

Deduction	Induction	Explanatory abduction	Innovative abduction
Premise $p \rightarrow q$	Premise $q$	Premise $p \rightarrow q$	Premise $q$
Premise $p$	Premise $p$	Premise $q$	Conclusion $p \rightarrow q$
Conclusion $q$	Conclusion $p \rightarrow q$	Conclusion $p$	Conclusion $p$

$p$  stands for any statement describing a design (the case),  
 $q$  for any derived property (the result) and  
 $p \rightarrow q$  for any generalisation upon which the inference 'rests' – a rule of thumb, a validated law, a scientific theory (the rule)

### Aim

- To test the model of reasoning proposed by Roozenburg (1993)
- To establish the pattern of reasoning in design activity

It is hypothesised that group idea generation is dominated by innovative abductive reasoning

### Research Methodology

#### Data Collection

- Protocol analysis of five groups consisting of three professionals presented with an industrial problem
- Three different design methods for idea generation. 20 minutes to brainstorm freely, followed by 20 minutes each with the two different methods – Random images and Bio-inspired cards (Ahmed-Kristensen et al, 2014).
- Participants were instructed to write or sketch ideas and to present all ideas verbally
- Each group was facilitated by a master student within engineering design and recorded with video cameras.



Example of Random image (left) and Bio-inspired card (right)

#### Coding

Coding scheme was developed and used to code data in the following steps:

- Episodes containing ideas and idea aspects were identified
- Episodes were coded for the elements of case, rule and result
- Inferences were identified assisted by argument conclusion indicator words. Remaining episodes were coded as incomplete



Stills from three of the groups participating in the study.

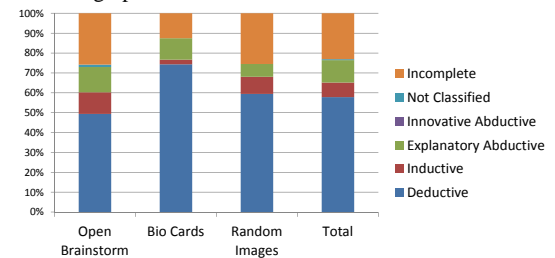
### Results and Discussion

**Reasoning pattern.** The observations were analysed and a total of 204 episodes were coded from the group, as presented in table below. Results were expected to show a high presence of innovative abductive reasoning in problem solving activity.

Type of reasoning identified in coded episodes	Count	Percent
Deductive	118	57,8%
Inductive	15	7,4%
Explanatory Abductive	23	11,3%
Innovative Abductive	0	0,0%
Not Classified	1	0,5%
Incomplete	47	23,0%
Total episodes	204	100,0%

- No cases of innovative abductive reasoning were identified
- 57,8% of all episodes were inferred using deductive reasoning

Differences in reasoning patterns for the three design methods used in the study are shown in below graph.



- The analysis suggests that participants transfer attributes of solutions presented on Bio-inspired cards to use as premises in a deductive inferences (74,3% of completed inferences, as opposed to average of 57,8%).

Below table shows the distribution of episode structures and shows that:

- 61% of complete episode inferences are not put forward at the end of an argument as proposed by formal logic of arguments.
- The form of these episodes are thus not considered valid in logical terms

Complete episode structure	Count	Percent
Inference expressed at end of episode	61	38,9%
Inference embedded in episode	67	42,6%
Inference expressed at beginning of episode	29	18,5%

From the results, we argue that:

- The deductive inferences present in the data are not based solely on fact, but to a large degree on conjectured premises
- A relation to innovative abductive reasoning exists, in that two elements of an idea are inferred.
- Bio-inspired cards design method suggests that the presence of solution analogies increases the use of deductively inferred premises
- Most inferences are made in a rhetorical manner similar to deductive reasoning
- Reasoning as arguments put forward in groups is likely different from reasoning in individuals.

### Implications

Roozenburg (1993), raises the issue of modelling nondeductive inferences in logical systems and similarly Toulmin (1958) raises the question of whether sound arguments must conform to requirements to form in order to be assessed rationally. In relation to the present study, these issues call for the development of a refined coding scheme to take into account 'invalid' arguments as well as the dominance of deductive arguments expressed during what is otherwise considered a nondeductive phase of the design process.

An improved coding scheme should attempt to further understand the influence different types of reasoning has on the idea generation phase in the design process. The importance of this is pronounced by the results of the study showing that a majority of ideas are deductively inferred in ways that, intentionally or not, potentially can sway or otherwise affect other group members. To further understand this phenomenon, analysing e.g. team mental models present could be promising.

