**INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED'07**
28 - 31 AUGUST 2007, CITE DES SCIENCES ET DE L'INDUSTRIE, PARIS, FRANCE

# CHARACTERISATION OF DESIGNER INTERACTIONS IN THE CREATIVE DESIGN PROCESS

**Mulet E[1], López-Mesa B[1], Gónzalez M.C[2], Camelo D[1]**

[1] Department of Mechanical Engineering and Construction. Universitat Jaume I de Castellón
[2] Departamento de Proyectos de Ingeniería. Technical University of Valencia

## ABSTRACT

This work analyses the interaction between the designer and the information that is presented to him/her during the creative phase, including the information that comes from other designers as well as from a computer display. Different types of interaction are identified and measured from video data and transcriptions of a design experiment, in which four teams of three subjects generate creative design alternatives to a given problem.
Finally, some of the relations that can arise between the problem-solving style, the method and the outcomes, and the degree and kind of interaction are presented.

*Keywords: creative design, interaction, empirical study, design process*

## 1 INTRODUCTION

The earliest computational models for supporting conceptual design used to be automatic and, thus, all the designer had to do was to introduce the definition of the problem at the beginning, usually as a definition of inputs and outputs. In recent years, several computational semi-automatic models have been defined that allow a higher degree of interaction with the designer. This interaction usually consists in selecting a set of design alternatives which have been generated at each cycle, some of which also allow the designer to define the weight of the evaluation criteria. These models include A-Design, Schemebuilder, among others, [1-6].
The possibility of obtaining a computational system to generate new solutions automatically during the early phases of the design process is a controversial issue. Several authors claim that computer-aided conceptual design should not substitute the designer, but instead allow the designer to be the one who guides the design process [7,8], which is referred to as interactive computer-aided design.
Many research works have focused on the analysis of the creative design process. In particular, several empirical analyses show that the results thus generated present different degrees of novelty and diversity depending on the evolution of the design process and on the actions performed by the designer during the design process [9,10]. Other studies also analyse the effect of creative methods on people's creativity [11,12].
Thus, further analysis of the creative process focused on designers' interactions is needed in order to gain new knowledge about creative design, which can be used in turn to define highly interactive computer-aided conceptual design systems and therefore to encourage the generation of better alternatives.
The aim of this work is to analyse the relation between the problem-solving style, the method and the outcomes of different forms of interaction between the designer and the information that is presented to him/her during the creative phase, which includes the information that comes from other designers as well as from a computer.

## 2 INTERACTION IN THE DESIGN PROCESS

The nature and kinds of interactions among the different design elements is a hot issue, as can be seen from the large number of studies appearing in the literature [11-17]. Each time an interaction takes place, an action comes about as a response or reaction by another member of the team (provided that the interaction with the knowledge becomes the ability to perform an action by the designer). In any case, the interaction and transmission of information and knowledge can come about either directly or by means of computational systems.

A designer's conception of a design and its context is built up over time using information from his/her existing knowledge and experience, as well as from external sources of information [13]. Several concepts should be taken into account in order to study and characterise interaction, which in turn implies stating who the actors involved in the interactions are, what the contents of the information exchanged are and what the scope of the information is [14].

The analysis of interaction needs to consider accessibility to information, understood as a subjective measure of the effort that a designer needs to make in order to access such a source of information. [15]. The interaction of the designer with instruments, like a computer, provides him/her with information. Sketches made using pen and paper are very intuitive to use, but new interactive devices and software must be developed, such as acoustic interfaces for virtual contexts, for instance [16].

In the same way a work concerning interaction proposes a methodology for capturing and representing information in large-scale design collaborations. As a result, a visual representation of interaction is obtained, in which measures like information entropy and semantic coherence are calculated [17]. In other studies, interaction is analysed from the point of view of relevance, which is the perceived degree to which information meets the designer's information needs while interacting [18].

With the aim to improve design team performance, analysing the interrelations of the members of design teams has been the object of several studies. A recent one explores the designers' interaction with information migrated from video clips, text-based documents, the World Wide Web and from other designers and they found that designers spend almost 50% of their time attending information sources and that some information sources were accessed more than others [19]. Based on these findings, these authors highlight the need for a better quantification of interaction; this objective has been also considered in the work presented in this paper.

## 3 DESIGN EXPERIMENT

An experimental analysis to study the effects that different idea-finding methods have on the design process and the outcomes of four design teams, and to compare these effects to those produced by the problem-solving characteristic of the team members, was preformed.

The participants were Engineering Design PhD students or doctors, most of whom had experience in designing. The KAI inventory [20] was used to identify the problem-solving style (innovative versus adaptive) of each individual. The task was to generate ideas for a tubular map case allowing one-by-one removal and insertion of maps. Two innovative teams and two adaptive teams with three members in each group were formed. One adaptive team and one innovative team used a hypothetically innovative method (SCAMPER) to solve the design problem. The other adaptive team and the other innovative team used a hypothetically adaptive method (visual stimuli). Each team generated ideas during a 45-minute period while being exposed to external stimuli from a computer at a constant frequency. These stimuli consisted in a set of images (visual stimuli method) and a set of questions about what to "substitute-combine-adapt-modify- put to other uses- eliminate-rearrange" (SCAMPER method).

Outcome-based and protocol analyses were performed to measure the influence of the problem-solving characteristic of the team members and of the methods in terms of the degree of novelty and other criteria, as is described in detail in [21].

Some of the design outcomes analysed were the number of alternatives and time dedicated to them and the degree of novelty of the alternatives that were generated. Figure 1 [21] shows the time of dedication to solution alternatives. It was concluded that teams inspired by SCAMPER questions showed preference for a solution to which the group dedicated time to develop further, whereas teams inspired by visual stimuli were in a continuous flux of solution alternatives generation without reaching a satisfying pair problem-solution. This was interpreted as due to the fact that SCAMPER allows designers to work within their own frame.

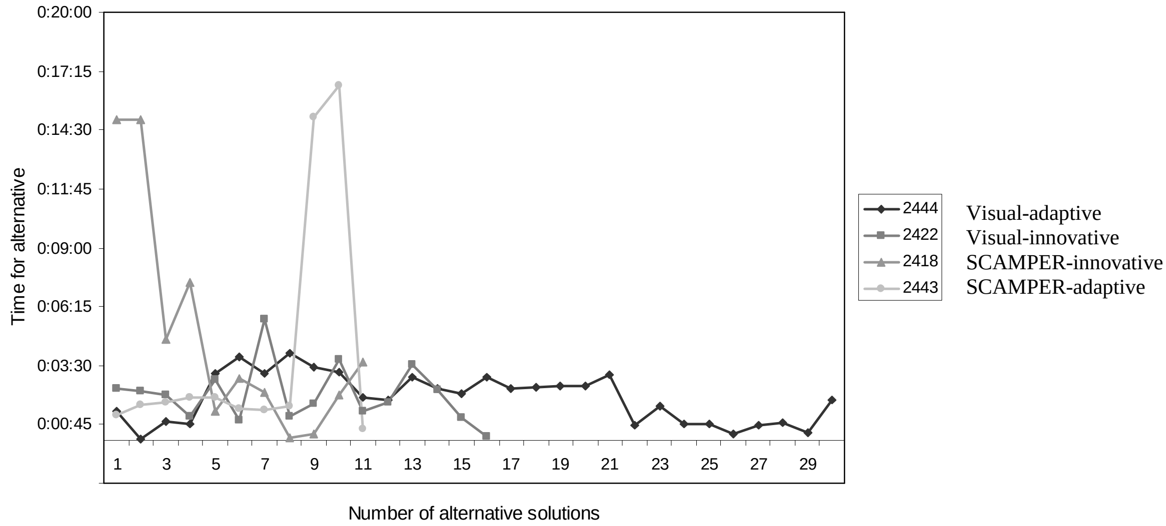


*Figure 1. Time of dedication to solution alternatives (from López-Mesa 2004)*

Novelty is a relative term and, thus, difficult to measure. A method was used [22] which takes into consideration the non-obviousness of solutions, considering that obvious solutions in the experiment are those that were produced by all teams and non-obvious solutions are solutions which few teams thought about. The method measures the percentage of solutions from a team that falls in each of the different levels of non-obviousness. Whether a solution falls on one level or another depends on the number of teams that have produced a similar solution. The solutions can be similar at different levels of abstraction, that is to say, two solutions may differ in a specific detail but their action function can be very similar. It was found that the main differences could be found at the action function level, shown in Figure 2.

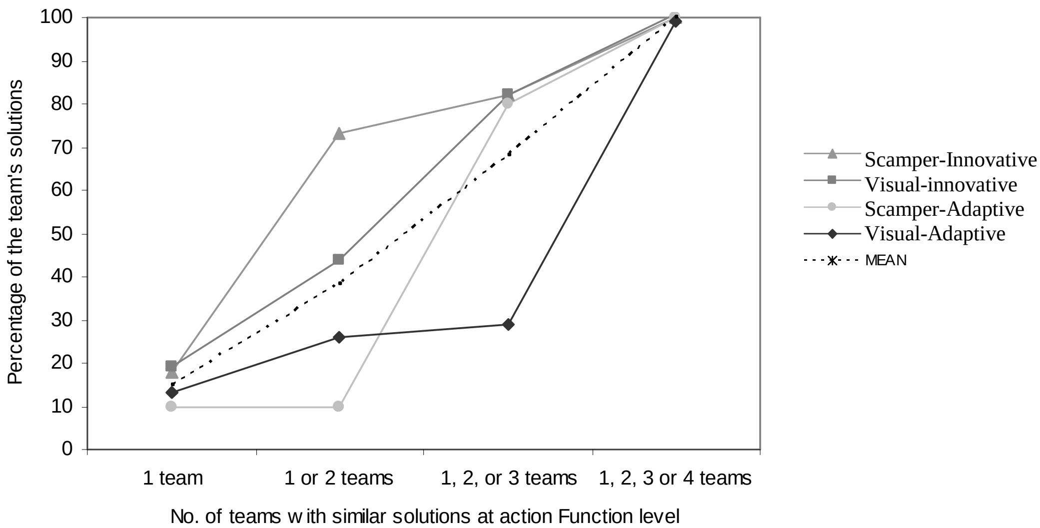


*Figure 2. Analysis of obviousness of solutions at action function level (from López-Mesa and Vidal 2006)*

At the Action Function level innovative teams produced a higher percentage of non-obvious solutions than adaptive teams.
This experiment is here used to analyse interaction.

# 4 ANALYSIS OF INTERACTION

In this section the experimental data are analysed from the point of view of interaction; this involves identifying how the design process is perceived by a designer throughout its evolution in time from one state to another, as well as how the designer reacts.

Design protocols were analysed and the designer activities were coded. These data were studied in order to identify variables and qualitative patterns in the interaction, and were also related to creative design process results in terms of the degree of novelty and the number of alternatives.
Interaction is a reaction that occurs as a response to external stimuli. From the analysis of the design protocols and the video data several types of interaction were identified and we classified them on the basis of two criteria:

- The type of answer or reaction produced in the interaction.
- The source of the interaction.

From the point of view of the type of answer, the following options were identified in the experimental data:

- The designer is accessing the on-screen information, but he/she gives no reaction. This kind of interaction is identified every time the designer looks at the screen, but after looking at it his/her next action has nothing to do with that information.
- The designer reacts with gestures or single utterances like "yes" or "this is already understood", etc. This kind of interaction is referred to as "formal interaction".
- When the formal interaction consists in asking someone, for instance, to explain something again or for their opinion, this is identified as formal-asking interaction and it produces a direct answer.
- The designer reacts to a particular piece of information by introducing new information about the design problem, or about an idea. This kind of interaction is named "content interaction".
- When the aforementioned interactions include a question, they are called "content-asking interaction".

From the point of view of the source of interaction, the following options are identified:

- The information on the screen.
- Another designer speaks about or draws something.
- A previous idea, that is, information that has previously been generated or expressed and which the designer uses again after ignoring it for some time.
- A physical object in the experiment room: a tubular map case, or a piece of furniture in the room.

As an example, Table 1 shows a piece of one of the protocol transcriptions and the interactions identified.

*Table 1. Example of interactions in the protocol transcriptions. Language in the experiment: Spanish*

| Time | Designer 1 | | Designer 2 | | Designer 3 | |
|---|---|---|---|---|---|---|
| 9:49 | 86. There are two ways. One is: there are all the coaxial tubes and, thus, the internal diameter, the one that [he is pointing to one previous idea], can be used as a spinning axis | **C1/ IDEA** | | | | |
| 10:02 | …Or… | | | | You can also do it | |
| 10:04 | Maybe that spinning axis can be used to contain something. […] | | | | with coaxial tubes as well | **C3/1** |
| 10:10 | The other one is… Now, let's see | | | | | |
| 10:13 | Coaxial tubes | | Yeah | **F2/1** | | |
| 10:14 | What you were saying, exactly what you were saying. But, how many [maps] could it hold? | **C1/3 C1→3** | | | [He draws according to what Designer 1 is saying] | **C3/1** |
| 10:17 | | | | | You can do it like this | **Answer** |
| 10:19 | How many [maps] do you think could be…? No, if we do it better, it will be easier. I | **C1→3** | | | [He goes on drawing] | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | guess… | | | | | |
| 10:26 | | | | | One into each one | **Answer** |

Symbols in the table:
**Fx/y:** x has a formal interaction with y **Cx/y:** x has a content interaction with y
**Cx→y**: content-asking interaction. It produces a direct answer or confirmation.
[…]: information between square brackets is added to clarify the protocol data.

# 5 RESULTS AND DISCUSSION

A design team is more or less interactive depending on the number of actions that its members perform as reactions to the external information and actions they receive. In order to measure and compare the interaction intensity during the design process, the degree of interaction is defined as (1):

$$M.D.I. = \frac{\sum_i I.D.I}{N} \quad (1)$$

Where:
M.D.I = Mean Degree of Interaction, which reflects the mean of the individual degrees of interaction.
I.D.I = Individual Degree of Interaction.
N = Number of members in the team.

And,

$$I.D.I. = \frac{N.I.I}{Interventions}, \quad (2)$$

Where:
N.I.I = A designers' total number of interactions in the session.
Interventions = A designer's total number of interventions, that is, the number of utterances or events that he/she makes during the session.
Table 2 shows the mean degree of interactions for each team, where the higher the obtained value is, the more interactive the team is.

*Table 2. Degree of interaction*

| | Scamper-Innovative | | | Scamper-Adaptive | | | Visual-Innovative | | | Visual-Adaptive | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Designer | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| No. Interactions | 97 | 132 | 79 | 170 | 132 | 89 | 91 | 98 | 65 | 51 | 55 | 72 |
| No. Interventions | 305 | 418 | 401 | 379 | 419 | 549 | 343 | 247 | 583 | 364 | 325 | 228 |
| I.D.I (%) | 32 | 32 | 20 | 45 | 32 | 16 | 27 | 40 | 11 | 14 | 17 | 32 |
| M.D.I (%) | 28 | | | 31 | | | 26 | | | 21 | | |

According to the results in Table 2, the teams are ordered from the highest degree of interaction to the lowest as follows:

1. Adaptive team using SCAMPER.
2. Innovative team using SCAMPER.
3. Innovative team using visual stimuli.
4. Adaptive team using visual stimuli.

This therefore enables us to observe the influence of the design method on the degree of interaction. Teams that use SCAMPER are more interactive than teams using visual stimuli. The problem-solving KAI characteristics show no influence in the analysed data. This could be due to the fact that the SCAMPER method allows designers to work with their own frames whereas visual stimuli leads the teams to change of frame continuously. This could be the reason why designers' emphasis increases and, indirectly, they are more interactive.

In order to explore and characterise the type of interaction in a design session, the percentages of interactions depending on the type of reaction and depending on the type of source are studied. The following subsections show these results.

## 5.1 Results concerning the reaction in the interaction

Figure 3 shows the resulting mean percentage of the number of each type of interaction for the teams.

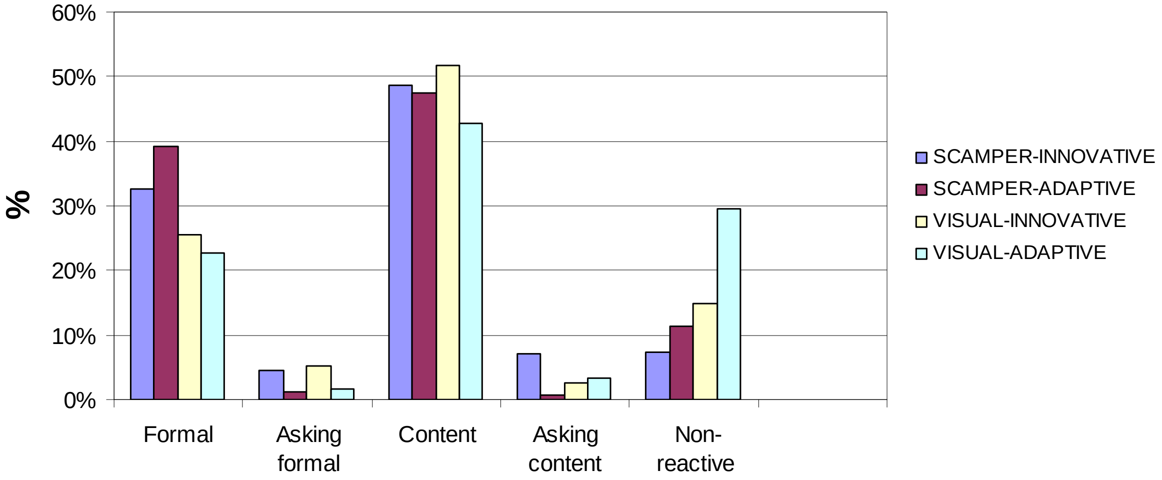


*Figure 3. Type of interaction*

According to the results, the most frequent interaction for all cases is the "content-interaction", which accounts for more than 40% of the total interactions. Although there are no big differences, innovative people present a slightly higher content-interaction than adaptive people.

The next most commonly used type of interaction is the "formal-interaction", which is more frequent when the SCAMPER method is used. A possible reason could again be that SCAMPER allows designers work with their own frames, provoking that a high number of formal reactions, such as approval of solutions offered by other members of the team, are produced.

Non-reactive interactions happen every time a subject looks at the computer display but no reaction is produced at all. This interaction is more frequent when visual stimuli are applied, as is explained in greater depth in the next subsection. The adaptive team using visual stimuli is the one with the highest percentage of non-reactive interactions, while the innovative team using the SCAMPER method is the lowest one. For the remaining types of interaction a very low frequency is observed.

## 5.2 Results concerning the source of interaction

Figure 4 shows the resulting mean percentage of the number of each source of interaction for the teams.

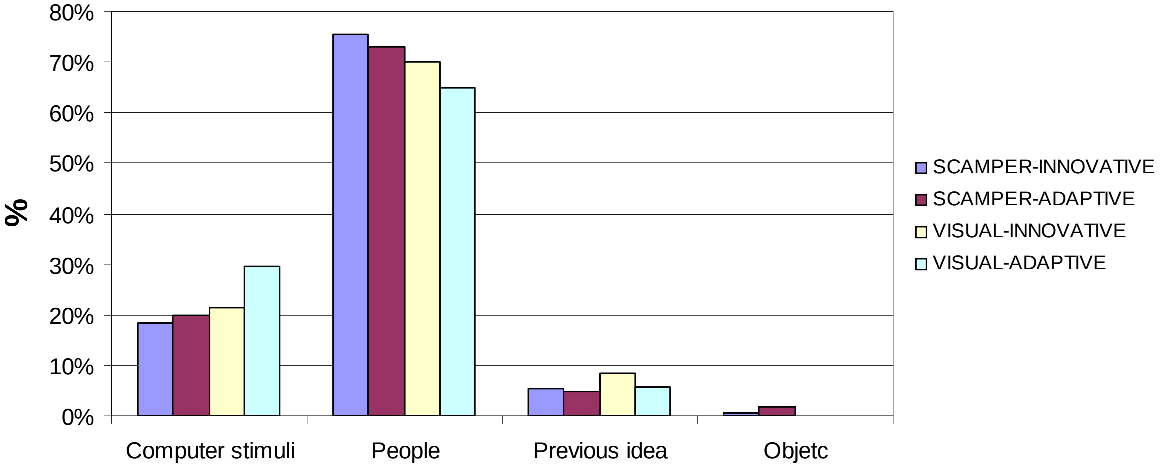


*Figure 4. Source of interaction*

In all the cases studied, the largest degree of interaction always corresponds to the interaction among participants ("people" in Figure 4) and is always close to 70% of the total number of interactions detected. The nature of this kind of interaction is quite similar in all cases, although it is slightly higher in those cases where the SCAMPER method was applied. Furthermore, in each method, the figure shows how there is always higher interaction among the participants ("people") in the teams with more innovative members. Finally, when comparing the total number of interactions among the participants, the adaptive team using SCAMPER method presents more interactions (331) than the innovative team using SCAMPER (285).
When analysing the results of the interactions with the computer display, it can be shown that this kind of interaction increases when visual stimuli are used. Indeed, this sort of interaction draws the designers' attention back to the screen more than the SCAMPER method, which is based on series of questions. In any case, one of the teams using the SCAMPER method has a level of interaction with the computer display that is very similar to another that uses visual stimuli (SCAMPER-ADAPTIVE and VISUAL-INNOVATIVE, respectively).
The main reason lies in the strong ability of images to recall our attention. Thus, designers tend to look at the information on the screen for a long time, even if, as usually happens in most cases, there is no reaction to this information.
Although the individual analysis of the data from the experiment reveals the same tendency or behaviour, in three of the four cases it can be noticed how there is a person with a stronger tendency to interact with the computer than with the other participants. A closer look at the videos provided an insight into the group dynamics – only in one of the groups was the interaction among the participants well-balanced. In the remaining cases it can be observed how there are two people with a higher degree of interaction between them, and a third one is largely excluded from the group dynamics, but does interact sometimes. As a result, this third member interacted highly with the information presented on the computer screen.
Also related with the group dynamics, in three of the four groups it can be observed that the people with a lower number of interactions with the group ("people") are the ones with a larger interaction with the computer.
The interactions with previously generated ideas represent from 5% to 8.5% of the total number of interactions, and are more common in the case of visual stimuli.
Only in the SCAMPER method there is explicit interaction with some of the objects existing in the work place (tube-based models or even furniture devices). In any case, these interactions, represent less than 2%, are rather small.

### 5.3 Interrelation with design process outcomes

From Figure 1 and Table 2, it can be deduced that the more interactive a team is, the highest the probability of working with its own frame. SCAMPER fosters a larger degree of interaction among the participants.
Unfortunately, due to the small number of experiments carried out in this paper, the relationship between the degree of interaction and the degree of novelty of the solutions generated can be determined only in a preliminary and qualitative way.

- The case with the largest number of different alternatives in terms of the action function level is the second one with a larger degree of interaction.
- The case with the lowest number of novelty solutions from the point of view of an action function level is the one with a lower degree of interaction.

In other words, there appears to be a slight correlation between the degree of interaction and the amount of novelty of the solutions found. Consequently, the larger the degree of interaction is, the higher the novelty will be. On the other hand, this relationship does not seem to be directly correlated, since the case with the largest degree of interaction is the third one in terms of the number of novelty solutions generated. Thus, a large number of cases for analysis are needed, before a conclusive answer can be given.

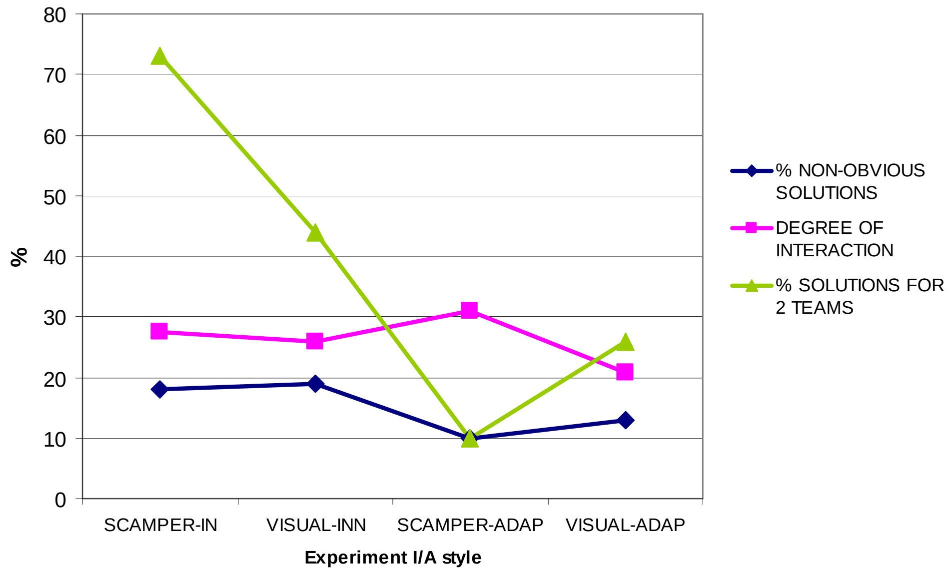


*Figure 5. Degree of interaction and novelty*

## 6 CONCLUSIONS

The work describes a way to explore interactions during creative design based on the analysis of protocol and video data. The degree of interaction is measured by a design experiment, and the interrelation between people's problem-solving styles and the method is also analysed. The main conclusions are:

- Around 25% of the designer's actions are interactive answers to another designer's actions, an object, a previous idea or information on a computer screen. Sometimes, there are double or triple interactions, that is, the designer's answer is given simultaneously to more than one source, such as the computer and another designer.
- When applying a method that encourages the generation of ideas that allows designers work with their own frame, the degree of interaction is a little bit higher than when a visual stimuli method is applied.
- The influence of the personal problem-solving style (innovative-adaptive) on the degree of interaction is not observed in the data analysed.
- Content-interaction is applied in more than the 40% of the interventions in all the cases. It has been observed that in teams with an innovative problem-solving style the percentage of content-interactions is slightly higher.
- Formal-interaction is the second most commonly observed type of interaction. Teams that applied the SCAMPER method carried out a higher level of formal-interactions than the others.
- The most frequent source of interactions, in all cases, is an action performed by the other designers, which represent around 70% of the observed interactions. In teams that use the SCAMPER method there is a slightly higher interaction with the other designers. The influence of the problem-solving style is lower, but it is observed that this source of interaction is higher in innovative people.
- When visual stimuli are used, the computer information is used significantly more frequently as a source of interactions.
- In each team, there is a designer that interacts less with the other designers and, thus, he/she displays a higher degree of interaction with the computer information.
- A comparison of available data shows that a higher degree of interaction is related to a lower number of design alternatives.
- The team with the lowest degree of interaction is the one with more obvious solutions. But there are no conclusive results about the relation between the degree of interaction and the novelty of the results.

It would also be interesting to expand these results in order to test other hypotheses, for instance, in those cases where the solutions found are a long way away from the paradigm, whether there is an increase in the degree of interaction or it remains the same. This kind of study should be carried out by analysing the degree of interaction in a local way, and in different episodes of the session.

These results can be considered in the definition of new computational models for supporting conceptual design. New procedures and options can be implemented in the reasoning schemes of these models in order to allow a higher interaction and consequently better results.

## REFERENCES


[1] Xu Q.L., Ong S.K. and Nee A.Y.C. Function-Based Design Synthesis Approach to Design Reuse. *Research in engineering design*, 2006, 17 27-44.

[2] Deng Y. *Functional Design of Mechanical Products: Design Model and Modeling Framework*, 2000 (Nanyang Technological University).

[3] Bracewell R. Synthesis Based on Function–Means Trees: Schemebuilder In (Eds) A. Chakrabarti. *Engineering Design Synthesis - Understanding, Approaches and Tools*, 2002 (Springer-Verlang)

[4] Campbell M., Cagan J. and Kotovsky K. The a-Design Approach to Managing Automated Design Synthesis. *Research in Engineering Design*, 2003, 14 12 - 24.

[5] Parmee I.C., Abraham J., Shackelford M., Rana O.F. and Shaikhali A. Towards Autonomous Evolutionary Design Systems Via Grid-Based Technologies. In *ASCE 2005 - International Conference on Computing in Civil Engineering, Vol.* Cancun, Mexico,

[6] Chakrabarti A., Langdon P., Liu Y. and Bligh T. An Approach to Compositional Synthesis of Mechanical Design Concepts Using Computers In (Eds) A. Chakrabarti. *Engineering Design Synthesis. Understanding, Approaches and Tools*, 2002 (Springer-Verlag)

[7] Candy L. and Edmonds E. Creativity Enhancement with Emerging Technologies. *Communications of the ACM*, 2000, 43 (8), 62 - 65.

[8] Parmee I. and Bonham C. Towards the Support of Innovative Conceptual Design through Interactive Designer/Evolutionary Computing Strategies. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing (AIEDAM)*, 2000, 14 3 -16.

[9] Chakrabarti A. Towards a Measure for Assessing Creative Influences of a Creativity Technique. In *International Conference on Engineering Design, ICED 03, Vol.* Stockholm, Sweden,

[10] Van der Lugt R. Relating the Quality of the Idea Generation Processs to the Quality of the Resulting Ideas. In *International Conference on Engineering Design, ICED 03, Vol.* Stockholm, Sweden,

[11] López-Mesa B., Mulet E., Vidal R., Bellés M.J. and Thompson G. Creativity in People Vs in Methods. In *AEIPRO - IX Congreso Internacional de Ingeniería de Proyectos, Vol.* Málaga, España,

[12] Vidal R., Mulet E. and Gomez-Senent E. Effectiveness of the Means of Expression in Creative Problem-Solving in Desing Groups. *Journal of Engineering Design*, 2004, 15 (15), 285-298.

[13] Eastman C.M. New Directions in Design Cognition: Studies of Representation and Recall In (Eds) C. Eastman, W. Newstetter and M. McCracken. *Design Knowing and Learning: Cognition in Design Education*, 2001 (Elsevier Science Press)

[14] Ge P. and Wang B. Assessing Product Developer-Supply Chain Relationship for the Eco-Conscious Design of Electronic Products. In *International Conference on Engineering Design, Vol.* Melbourne,

[15] Borlund P. The Iir Evaluation Model: A Framework for Evaluation of Interactive Information Retrieval Systems. *Information Research*, 2003, 8 (3),

[16] Rolshofen W., Dietz P. and Shchäfer G. Innovative Interface for Human-Computer Interaction. In *International Design Conference-DESIGN, Vol.* Dubrovnik-Croatia,

[17] Dong A. and Vande Moere A. Visualising Collaboration in Very Large Design Teams. In *International Conference on Engineering Design, Vol.* Melbourne,

[18] Restrepo J. Assessing Relevance: Designers' Perception of Information Usefulness. In *International Design Conference-DESIGN, Vol.* Dubrovnik-Croatia,

[19] Eris O., Mabogunje A., Jung M., Leifer L., Khandelwal S., Hutterer P., Hessling T. and Neeley L. An Exploration of Design Information Capture and Reuse in Text and Video Media. In *International Conference on Engineering Design, Vol.* Melbourne,

[20] Kirton M.J. *Kirton Adaptation-Innovation Inventory. Feedback Booklet.1985, 1992*, 1999

[21] López-Mesa B. *The Use and Suitability of Design Methods in Practice. Considerations of Problem-Solving Characteristics and the Context of Design*, 2004 (Luleå University of Technology).

[22] López-Mesa B. and Vidal Nadal R. Novelty Metrics in Engineering Design Experiments. In *Proceedings of the International Design Conference - Design 2006, Vol.* Dubrovnik - Croatia, pp.557-564



*This work has been supported by the Programme Alban, the European Union Programme of High Level Scholarships for Latin America, scholarship no. E04D030611BR*



Contact: Dr. Elena Mulet
Universitat Jaume I
Departamento de Ingeniería Mecánica y Construcción
Avda Sos Baynat s/n
12071 Castelló. Spain
Phone: +34 964 72 8117
Fax: +34 964 72 8106
e-mail: emulet@emc.uji.es