DO COMPUTER MEDIATED TOOLS AFFECT TEAM DESIGN CREATIVITY?

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Abstract. This paper presents the results of a quantitative analysis to measure the development of creative design ideas in design protocols. It presents a working definition of design creativity used in the analysis followed by the method of study. Five sets of video and audio data were collected from experiments that involved two designers designing similar tasks in three different settings: face-to-face, an Internet GroupBoard, and a 3D virtual world. The most creative pair was selected for qualitative and quantitative analysis. Our result shows that designers developed more design ideas in the face-to-face setting than in the 3D virtual world settings.

Keywords. Creativity, protocol analysis, collaborations, virtual world

1. Introduction

Creating is one of the most important activities in designing. Designers often need to collaborate because of the complexity of the problem, the need for specialized expertise, and the involvement of users to identify requirements. Increasingly such collaboration occurs at a distance with the support of computational technologies and networks at various levels. Despite such modern technologies, research shows face-to-face interaction is still one of the most important elements for developing ideas (Oslon and Oslon 2000, Salter and Gann 2002). Team design activities are not only influenced by social process such as roles and relationships but also the technologies being used (Cross and Cross 1995). However, quantitative methods for studying team creativity are lacking. There are CAD tools that claim to support distance collaborations, can they support team creativity as well? The effects of computer tools upon team creativity are not well understood. The aims of this study are: to develop technique to study creativity quantitatively; and to

examine the effects of computer mediated collaboration tools upon creativity.

2. What is Creativity?

Merriam-Webster's dictionary defines creativity as: 1) the quality of being creative, 2) the ability to create. There are various definitions of creativity in different fields (Taylor 1988). In the design field, creativity has long been one of the most important criteria of measuring the artifact. Creativity is associated with terms like 'originality' and 'novelty'. In designing it also connotes utility and unexpectedness.

Boden (1990) introduced "historical" creativity and "psychological" creativity to differentiate social-historical creativity from individual creativity. Suwa et al. (1999) added the term "situated creativity" to identify creativity during the process of designing rather than considering the outcome. Human creativity can be considered as cognitive processes that generate novel ideas within a relevant context. Goldschmidt and Tatsa (2005) believe that creative products embody 'good ideas' and the goodness of ideas can be discerned by using the linkographic technique which connects ideas that share enough commonality. This paper extends the construction of linkographs with codes that categorize segments of protocols into Function-Behaviour-Structure (FBS) classes (introduced in Section 5.1) and the links between these segments become transformation processes. We consider creative processes involve the introduction of new FBS variables in relation to existing variables or context. As a consequence the reformulation processes are vital for creativity because they introduce new variables and are the potential loci for creativity.

3. Method

The data collection was through in vitro experiments with five pairs of designers designing similar tasks in three different settings: face-to-face, an Internet GroupBoard, and a 3D virtual world. Prior to the computer-mediated experiments, there were training sessions to acquaint the participants with the operations of the different environments. The design sessions were either video taped or digital video recorded with four views, Figure 1. In the case of computer-mediated sessions, their screens, with full resolution, were also captured at the rate of three frames per second. Maher et al (2006) provide a detailed description of the experimental setup.

Of the 15 design sessions the most creative face-to-face session, judged by the design outcome, was selected for analysis and compared with their 3D virtual world session. The GroupBoard session was not studied due their lack of distinction from the face-to-face session. Maher et al (2006) have shown in their analysis of the GroupBoard session that the designers' behaviours were either similar to the face-to-face session or in the mid-ground between the face-to-face and 3D virtual world session.

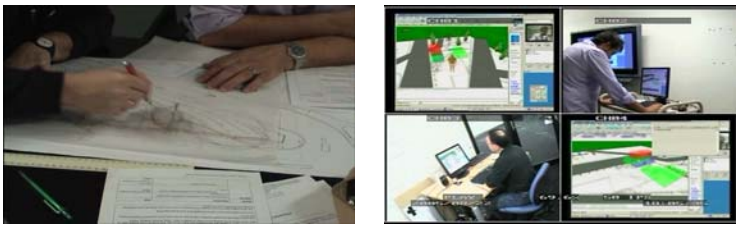


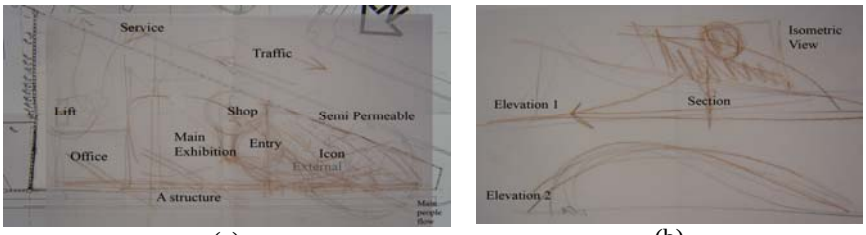
Figure 1. Raw data of face-to-face session (left) and 3D virtual world session (right)

Protocol analysis is the method employed to generate and analyse data. Our approach involves: 1) qualitative assessment of the data; 2) abstracting idea segments from the raw protocol; 3) coding these segments using an ontological coding scheme (Gero 1990, Gero and Kannengiesser 2003); 4) connecting these idea segments using linkography (Goldschmidt 1992); 5) deriving design processes from links; and 6) studying these derived processes in relation to creativity.

4. Qualitative Analysis

The team was asked to design a contemporary art gallery and a dance studio in the face-to-face condition and in the 3D world respectively. The same site was used and the complexities of the briefs were comparable. A1 and A2 are used to represent the two participants in this paper. In both sessions A1 seemed to take the leadership role and made decisions; he drew most of the sketches in the face-to-face session and organized most of the activities in the 3D virtual world session.

The face-to-face session can be divided into four stages or episodes based on the design activities. In the first episode they dealt with the brief and site (about 3.5 minutes); in the second episode they analyzed, planned and developed concepts in the plan, Figure 2(a) (about 9 minutes); in the third episode they developed the 3D form in elevation, Figures 2(b) and 3(b) (about 9 minutes); and in the final episode they worked on the layout in the plan until the end (8.5 minutes), but they did not finish it within the 30 minutes allocated for the session.



(a) (b)

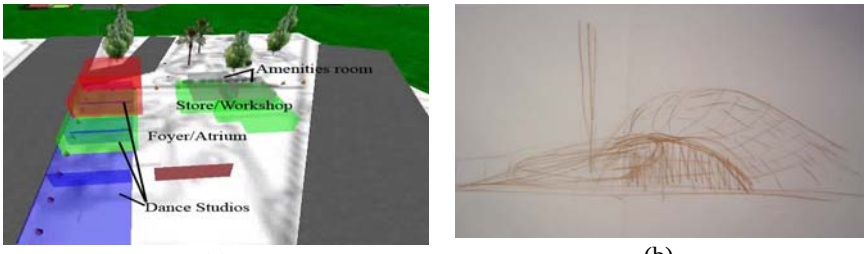
Figure 2. Plan and elevations of the face-to-face session.

They started by analysing the site, both of them knew the site although A2 got orientation wrong. In the second episode, from the site analysis A1 suggested the location of the main approach and started drawing. A2 suggested the location of service entrance. Issues like an icon to capture

attention, internal and external relationships, and permeability were discussed. Also, the location for the main exhibition, the back of house, and a merchandising area were suggested, Figure 2(a). Afterwards A2, using another sheet, Figure 2(b), suggested the elevations but A1 provided a counter proposal by drawing an isometric view, Figure 2(b). Eventually A1 drew the 3D form, Figure 3(b), in the third episode. In the last episode, they tried to resolve the dimensions and constraints of the design which involved a lot of calculations.

In the 3D world session, the stages were not as well defined; they spent less than 2 minutes with the brief before exploring and making objects. This session can be characterized as "designing through making". Sometimes they subdivided the tasks and work individually. They were given pre-defined elements – space, slab, wall, column, and beam – at various sizes. They decided to start with the biggest space element to represent the "largest" spaces – the four studios. At around 12 minutes, they discovered they could not have all the studios on one level because of the site coverage constraint. A1 decided to stack them and create an atrium to join them together. They tried to further develop this concept to accommodate the requirements, Figure 3(a). A1 repeatedly went to pick up those space objects of relevant size for A2 to arrange on the site.

They did not finish the design and left out elements such as connecting bridges and some functional spaces. Besides designing, time was spent on design support activities such as discussing what elements were available and organizing what to do. Also time was spent on technical aspects of learning how to do things like change the colour of the blocks, how to fly, and how get out when trapped inside those blocks.



(a) (b)

Figure 3. Comparing the three dimensional form of the two sessions.

2.3. COMPARING THE TWO SESSIONS

From Figure 3 we can see the styles of the designs are very different. This section compares the two sessions.

In the face-to-face session the design process was closely coupled while in the 3D virtual world session the process was loosely coupled. In the 3D world session they tended to work more individually leading to the issue of the sense of presence. They used the webcam and avatars to detect each other. However, we found statements in the protocol like: "…you're not looking my way anyway", "the camera is not directed at you", and "I can't see you though…, I don't know where you are…" Also, they lost the ability to gesture. The design actions were through interaction with keyboard and

mouse. In the face-to-face session they relied on gesturing to communicate, they gestured paths, shapes, and circulations. They also used gestures to signal drawing turn taking.

The length of the verbal protocol in the face-to-face session was not only longer but also more concentrated on designing. There was more non-design activity in the 3D world protocol. For example communication regarding the software: "how do change the colour", communication related to the location of each other: "where are you", communication regarding the ownership of objects "now you've taken it away", and other social communication: "it's superman". The amount of time they remained silent was also longer in the 3D world session. Even in design related communication, they were more about achieving tasks; this can be explained by the limitation of the software, for example "I pick it up…", "we bring it across…", and "… because it is filled by blocks".

They developed more design ideas in the face-to-face setting than in the 3D virtual world settings. There were a number of concepts beside organizing the space like 'make it a journey of discovery", "the ribbon idea", "hole in the middle", "ramping … this whole platform", "dropping into the centre". These ideas co-evolved in the problem and solution space and it is hard to pinpoint what triggers these ideas. What was observed matched what Finke (1992) described as many processes collectively setting the stage for creative insight and discovery. In the 3D world session, the main idea was the "atrium". Although there were fewer ideas they still switched between the problem and solution spaces.

5. Quantitative Analysis: Ontological Coding

The design protocols were segmented according to the FBS ontology. The FBS framework (Gero 1990) models designing in terms of three class of variables: *function*, *behaviour*, and *structure*. In this view the goal of designing is to transform a set of functions into a set of design descriptions (D). The function (F) of a designed object is defined as its teleology; the behaviour (B) of that object is either derived (Bs) or expected (Be) from the structure (S), where S describes the components of an object and their relationships. Figure 4(a) shows the relationship among the eight transformation processes and the three classes of variables. The problem space and the solution space are expanded by the introduction of new variables through reformulations.

Gero and Kannengisser (2004) integrated the idea of situatedness into the FBS ontology to form the situated FBS framework by introducing interactions among three worlds – the external, interpreted, and expected world. An agent or human interacts and understands the external world through their interpretation of the external world to form memories of his interpreted world. In order to change the external world (the act of designing) he needs focusing to transform memories to the expected world before taking action in the external world. In this framework the original eight processes are expanded to twenty to account for all the processes, Figure 4(b).

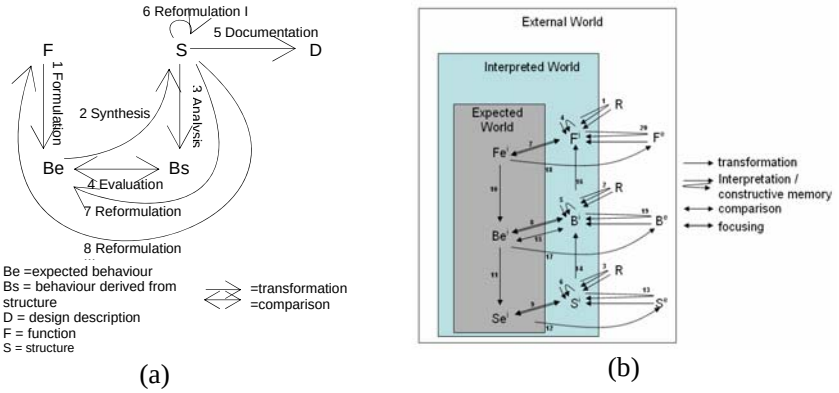


Figure 4. (a) FBS ontology, (b) situated FBS ontology

Table 1 is an extract of the coded protocol of the face-to-face session. The segmentation is based on the FBS ontology. Segment 13 was a response triggered by attending to the requirement of "size" in the brief. The architect was expecting to obtain structural data, pulling data, from the brief, therefore it was coded as "S^i" Segments 14 and 16 were reading from the brief so they were coded as "R". Segments 15 and 17 were the interpretation of the behavioural and structural requirements, so they were coded as "B^i" and "S^i" respectively. Segment 18 recalled a famous museum by Frank Gehry. From the context it seemed to refer to the structure, expecting the gallery to look like "the Guggenheim". This gave a new meaning to the understanding of the design. In segment 15 the architect interpreted the gallery as "typical" when referring to the "permanent and temporary" collection space; this interpretation was changed in the light of the current situation. We anticipate studying this kind of reformulation process may give us some insight into the creative process.

We coded the first 11 minutes of both sessions. There were 205 segments and 95% of them contained FBS codes in the face-to-face session. There were 125 segments in the 3D world sessions and 51% of them contained FBS codes. The low percentage in 3D world was a result of learning how to do things, especially in the beginning, like "how to fly", "how to get out", and "how to change colour". Actions of mouse and keyboard in the 3D world session were not segmented. So no external world actions were coded. However, there was a high percentage of structure which corresponded to the "design by making". Figure 5 compares the percentage of codes of the two sessions.

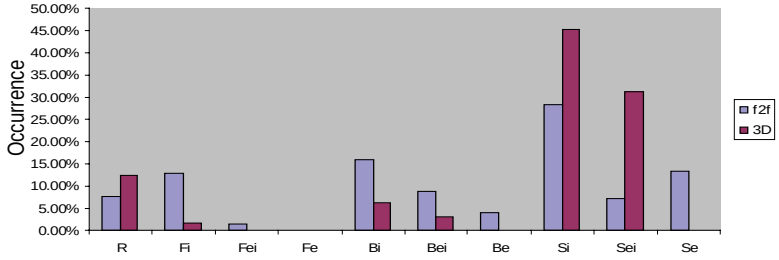


Figure 5. Percentages of codes in both sessions.

TABLE 1. The coded protocol according to the situated FBS framework.

Segments	Protocol	Code
13	Okay hang on, it's talking about sizes here.	S^i
14	So… (read brief) permanent and temporary	R
15	typical.	B^i
16	(read brief) Permanent collection is 200 and 50 meter hanging space.	R
17	50 meter hanging space!	S^i
18	This is the Guggenheim	Se^i

5.1. DERIVING PROCESSES FROM LINKOGRAPH AND FBS CODING

Figure 6 shows the coded protocol together with the linkograph being constructed by discerning if segments are related (Goldschmidt 1992). We consider each link as a process that transforms one state variable to another, for example the link between Segments 14 and 15 are the transformation of R to B^i, represented by the $R \dashrightarrow B^i$. There are 619 links, hence 619 processes, in the face-to-face session. Some of these processes are meaningless because some segments do not have FBS codes. Figure 7 summarizes the percentages of these processes in relation to the eight FBS processes.

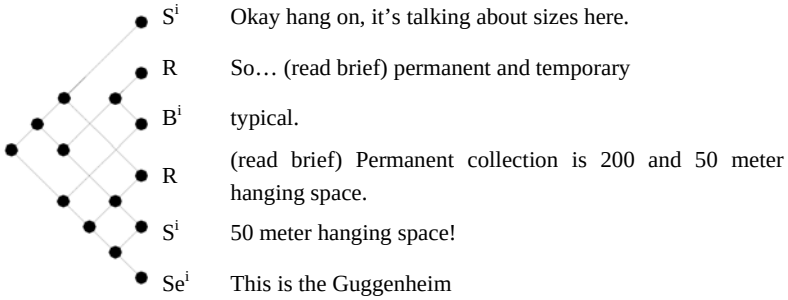


Figure 6. Example of linkograph in relation to protocol

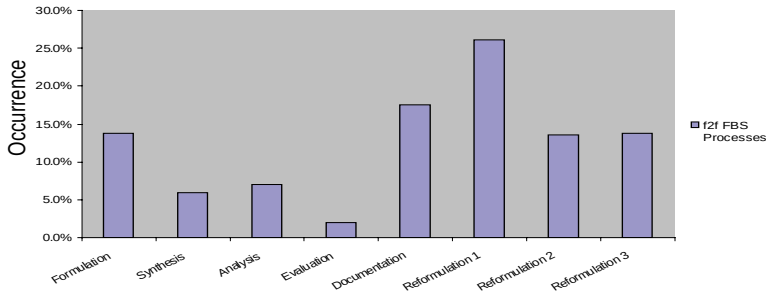


Figure 7. Example of linkograph in relation to protocol coding

6. Conclusions

In this paper we selected two design sessions, out of 15, to analyse qualitatively and quantitatively. In the quantitative analysis we refined linkography by discerning how the moves were linked to terms of the FBS ontology. By doing this we were able to capture not only the structure of

design reasoning but also the semantics involved. It showed that the 3D world session was dominated by reasoning about structure while in the face-to-face session they reasoned about all the three classes of variables. This corresponded to the qualitative assessment.

Ontological processes were derived from the coded linkograph. There were more reformulations in the fact-to-face session, and all three types of reformulations were present with relatively high percentages. This matched our understanding of creativity being connected with new FBS variables. More investigations are required to draw more general conclusions.

Our results confirm those of Maher et al (2006) that the design processes are quite different in sketching and 3D virtual environments. Our analysis in this case study shows that designers developed more design ideas in the face-to-face setting than in the 3D virtual world settings. In the most creative face-to-face session, creativity starts with the interpretation of the brief. The frequent use of gesturing the shape resulted in a more creative form. The 3D virtual world settings had less moves both in terms of quantity and semantics. The quantitative, ontologically based analysis of the protocols provided evidential support for the conclusions reached. Further, we speculate in order for any computer mediated tools to support design creativity they need to capture not only the geometries but also the behavioral aspects of designing.

Acknowledgement

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