A Comparative Study of Protocol Analysis in Traditional Media, Computer Media and Network Environment

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The report discusses the nature of the virtual space by examining the creative verbal language and visual elements that involve the sense of space. Moreover, the report also discusses the feasibility of the usage of verbal analysis in the computer and network environment. All the verbal and visual elements of space that have been found through our experiments and interviews are presented here. In addition, the issues concerning the methodology of the verbal analysis have been pointed out with quantitative and qualitative analysis, and an amendment formula has been suggested. Finally, the researchers also explore the comparison of the spaces that are created verbally and visually, as well as the comparison of the actual and virtual spaces.

Keywords*: Protocol Analysis; think-aloud; computer media; network environment; methodology.*

Introduction

Protocol Analysis (PA), a subject that originated from cognitive psychology and cognitive science, was used to investigate the mental process of human thinking. By the 70s, Eastman (1970) used PA to research on direct view design processes, introducing design sciences into the world of methodical research. From the 80s onwards, PA is used in into other design processes, e. g., engineering design, software design or industrial design. Research into design processes and the cognitive activities of designers appeared in abundance, and PA become the main methodology for this science (Akin, 1978, 1993, 1995; Schon & Wiggins, 1992; Lloyd & Scott, 1995; Gero & Neil, 1996; Cross et al, 1996; Oxman, 2001).

Gero and Neil (1996) integrated a coding system to strengthen verbal analysis (VA). This research, based on the characteristics of common media, inherited the method of think-aloud from psychology in the data-gathering stages of research design activities, but this cannot prevent restrictions regarding interference during the design process. Therefore, Suwa and Tversky (1997) put forth the concept of verbalization methods based on video/audio retrospection, providing audiovisual materials to assist designers in their retrospection of the design process, supplementing the restrictions that result from short-term memory issues, and avoiding the limitations imposed by simultaneous think-aloud reports on cognition. Therefore, think-aloud and video/audio retrospection has become the main methods of data gathering for verbal analysis. (Gero & McNeill, 1998; Purcell and Gero, 1998; Tang & Gero, 2001).

Drawings and the knowledge and memory (including the interactions between long-term and

short-term memory) inspired by viewing drawings and other cognitive behaviors have always been a key part of the design thinking process? Schon and Wiggins 1992; Liu, 1995; 1996?. At the start of a design process, designers derive many ideas that evolve through the drawing of sketches which can be derived, modified, perfected or merged in chorus. Sketches effectively are the design tolls of designers (Schon, 1983; Goldschmidt, 1994).

Goldschmidt (1994) observed that sketches provide designers with indications on investigations of special characteristics not otherwise recognized. A typical example is the exploration of spatial relationships, for example, proximity or spatial characteristics and shapes, which are by-products of sketching not otherwise thought of. In cognitive psychology, academics have advocated the view that human ideas on space originate from the establishment of a recognition structure (Harvey, 1989). Perceptions of space, in fact, are accumulations from experience through self-verification and organization creating „space" that differs for every person. For human mind and thinking, this space that comes from new media and new interfaces deliver a vastly different spatial experience that, through human feelings and recognition becomes an extension of the real space? Anders, 1998?.

The involvement of computers in design in recent years has resulted in the rapid development of computer-assisted systems and the use of computer media for recognition research into thinking developments (Wong, 2000; Chen, 2001), which resulted in the discovery that verbal analysis (VA), at present, does not give enough information when used in computer media research; therefore, VA needs to be modified to fit the special characteristics of computer media. In the research of Gross et al (2001), attempts were made to solve issues in VA records.

On the other hand, the development of the cyberspace has not only meant research into the special characters of the networked space but also into a new method of communications altogether through the maturity of internet technologies. (Chang, 1999; Maher, 1999; Gabriel and Maher, 2000). This topic has not only attracted the attention of the fields of architecture or design (Mitchell, 1999), but Liu (2001) also advocated thinking models under the space of the Network Environment.

However, even though research into the Internet has only started, if research into methodologies cannot keep pace, investigations into design activities under the Network Environment (NE) will face bottlenecks. Modifications must be made in response to media characteristics. Therefore, this Research centers on differences in research methods for VA under traditional media, computer media and NE, which VA techniques are suitable for computer media, and whether VA can be used for research under the Network Environment?

For cognition, people and designers in the real world experience space through various organs. Human cognition comprises sight and verbal communications. Different media present different spaces. As the reappearance of design knowledge is primarily through the reappearance of verbs; communications and sight, this Research is also focusing on investigations into VA and viewing spectacles in space. Therefore, this Research's objectives is to investigate on VA methodologies for computer media and the Network Environment (NE) based on traditional VA methodologies after an investigation into the characteristics of computer media and the NE, and compare differences in thinking and recognition under the three environments.

Procedure and Results of the experiments

Methodology and Steps

In the research of Liu (2001), architectural design process media were shown to be inter-related. To demonstrate the spatial ideas inherent in the thinking of designers, in the design process, by conven-

tion, designers use traditional media (sketches, handwriting notes, and actual models) to present traditional spatial elements in comparative systems. In these media, we can see leads in our thinking inherent in our brains. Therefore, based on the design materials (paper and pencil sketches) (Figure 1) of Schon & Wiggins (1992) to compare the design thinking of designers under traditional media (TM), computer media (CM) and Network Environment (NE).

To compare the differences in PA under TM, CM and NE, and to put forth modifications to the PA to make it suitable for CM (i. e., a "CMPA") and the NE (i. e., a "NEPA"), this Research involved four stages.

Stage 1: VA experiments: under the three environments, TM (actual models), CM (modeling, virtual reality (VR), etc.) and NE (design activities through web sites), one experimenter with design experience was chosen to record experiments through the think-aloud method. The experimenter completed design analysis in 15 minutes for the entrance to a library. To avoid interference between the three experiments, they were held five days apart of each other, and interviews were held after the experiment. Stage 2: Analysis and modifications: after data from the experiments were obtained, they were parsed and coded to be used as the basis for analysis, to obtain a CMPA and a NEPA after modifications. Stage 3: Verification experiments: research methods obtained were verified under the CM and the NE. Stage 4: data from verification experiments were comprehensively analyzed to develop detailed and clear PA methods and methodologies for CMPA and NEPA.

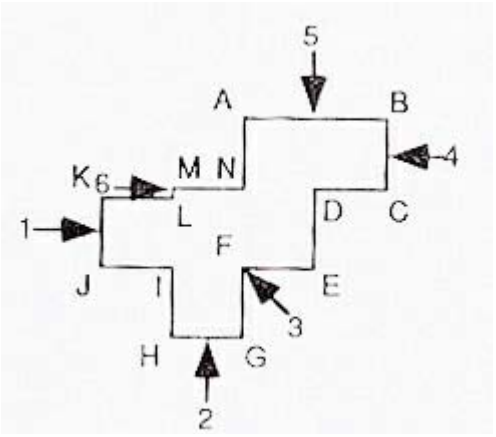

Figure 1. Design material (after Schon & Wiggins, 1992).

Experiment Process

To a large extent, design is "making and seeing; doing and discovering". Schon & Wiggins (1992) put forth perspectives in design investigations and described their various uses. Liu (2001) mentioned that all experimenters said that actions, interactions and sound effects were all major elements in the feeling of space, rather than the formal dimensional shapes expected by architects. Therefore, this Research, will minimize variables in the design recognition process, i. e., only using basic structural combinations and not materials, and design experiment samples based on the special characteristics of the media, in order to make the basic characteristics of the three experiment samples as similar as possible to deliver effective samples (Figure 2). For design expressions, computer rendering and the definition of outside materials are both detailed designs, and this Research has strived to remove the advantages of computers in this area to facilitate experimental equivalence.

Coding Scheme System

This Research's experiment process uses think-aloud data from the experimenters as the main data for analysis. To plug any gaps, verbal information supplemented by sign information is also used, i. e., after the experiments are completed, experimenters are interviewed for certain detailed issues while memory of the design process is still retained in order to collect supplementary information for VA.

This Research uses quantitative and qualitative analysis systems. In the quantitative analysis system, three sub-items were coded based on the total volume in VA. The first sub-system is S-NS, repre-

Figure 2. Experiment process under the three environments

senting the short term memory thinking of experimenters in the idea formation stage. The second sub-system is the FU-FO system, investigating the influence of the involvement of space for experimenters in functions and form. The third sub-system is VI-NVI; elements that appear and that are operated upon in the design production process are usually visual; however, those are not to aid thinking and decisions made for design. The qualitative part comprised primarily of the perspectives analysis of observers, and a comprehensive analysis of the interview information.

Schon and Wiggins (1992) believes that design is formed from a process of "seeing-moving-seeing", including visual apprehension of shapes on paper, judgmental evaluations of design quality, and understandings of spatial behavior. Figurative spatial expansions through spectacles allow the duplication of memory and the transfer of knowledge. Therefore, to investigate short term memory, the use of design knowledge is relevant. Functions and form are the two basic elements most focused-upon in spatial recognition, and are the two simplest factors in judgmental thinking. The two recognition processes, visual information and non-visual information, were put forth by Suwa and Tversky, 1996, and were used to develop sketching behavior through such models, and such analyses include elements that are described, the special characteristics and properties of elements, spatial relationships, functional thoughts and design knowledge. Non-visual information includes functional thoughts and design knowledge.

Comparison and Analysis of the Cases

Heterogeneity of actors

When the suitability of VA on various environments is considered, it is imperative for the differences between the three environments to be considered. In traditional media models, the number of times the experimenter looks at the surface is reduced as times go on, and the number of times the experimenter looks at the three dimensional facet increases proportionately to time. Therefore, in a model, three dimensional movement helps the distinguish and recognition of space, and the angles of movement and the subspace created helps the judgment of the experimenter.

In the second part (CM experiments), the interactive mechanism and changes in the perspectives of the viewer inspires spatial outlooks and proximity. In the computer models, experimenters need to use the mouse and the keyboard arrow keys to change perspectives. Obviously, we have eliminated variables in operation from the familiarity of the experimenters to the system, as experimenters are fairly competent in computer operations, and can clear see and judge spatial outlooks and measurements. Overhead views are needed to judge the overall dimensions of the space, and the interactive mechanism helps experimenters to compare the proximity of the walls in the movement process, to accurately judge the placement and planning of the space.

Under a Network Environment (part 3), the NE experiment is computer based, and avoids the linear

structure of traditional documents, and stores information in interlinked nodes to allow users to go through links to navigate freely in the database. Browsing is the method of viewing in a NE, and the experimenter moves through links, i. e., as the system presents data through processes, the path built by the user is that given by default by the system, and, through linkages, demand for examples exceeds that of surfaces, but time-wise, flat two-dimensional maps is the most important piece of information for the experimenter in building this network map.

Sophistication of seeing

This Research has also mentioned that lines seen can be considered a spatial pattern, created mainly through the association of the designer. "Association", formerly a jargon in psychology, is used by linguists to describe links between words. Perspectives differ; some have advocated the theory of "association field through form or definitions research, dividing the idea of association into "form association" and "related association. In this Research, "Related Association" (RA) takes precedence over form association. Models, like all charts, comprise of inter-related elements arranged in space, and forms levels and frameworks for reference materials. Interpreting a model refers to grouping or eliminating certain elements, and is similar to designating one reference framework or level. Changing any one of these relationships results in new interpretations of the space, inciting new design ideas.

Early designs lean towards ambiguities; as the ideas are clarified, the ambiguities disappear. Ambiguities play an interesting role in re-interpretations: if sketches are ambiguous, re-interpretations are easier (Goel, 1995); however, if sketches are very ambiguous, designating one interpretation becomes more difficult. Models, however, can further verify the utilization of thinking, and pen-and-paper sketches need not be used to express and interpret. Models convert design thinking into concrete artistic images; and not just expressions of design. Architectural models is a major method to express architectural performance; even if expressions are perfected with today's computer technologies, computer models can use its unique artistic qualities and real and spatial formulation powers to express the feelings of the designer and create a supplement for 2D drawings. Models, as concrete objects, gives designers more direct feelings, and can not only be observed from a fixed perspective, but browsed and explored from a multitude of angles.

Detailed Analysis in Research Methods

In the table below (table 1), this Research examines through quantitative and qualitative analysis to investigate on whether VA research methods can be used on TM, CM and NE environments. Below, PA on TM is referred to as TMPA, PA on CM is referred to as CMPA, and PA on NE is referred to as NEPA.

Qualitative Analysis

Coding analysis of observations and interview results were used for qualitative analysis. In TMPA, from the view of the observer, the orientation was ambient; perspectives can be moved at will and without restrictions. In interviews, the experimenter believes that concrete models are most helpful in thinking.

In CMPA, orientation is expressive; the characteristics of the mouse and the directions of the cursor is to some extent a simulation of the pen's functions, but interactive processes cannot be recorded effectively by think-aloud. In interviews, the main complaints were the inability to immediately change to the previously-seen angle, and that the interactive mechanism is sometimes interfering.

In NEPA, orientation is not expressive; through following links, experimenter can browse by pressing the anchor on the source node to reach the destination node. Default paths are sometimes restrictions, and not necessarily the angle or information required by the experimenter, creating excessive restrictions.

		TMPA	CMPA	NEPA
Quantitative Analysis	**Total number of VERBAL words**	2796	3432	3515
	STM vs. Non-STM	1600 vs. 973	1646 vs. 850	653 vs. 2464
	Function vs. Form	534 vs. 449	224 vs. 630	210 vs. 705
	VI vs. NVI	816 vs. 1757	1621 vs. 500	790 vs. 420
	Invalid data	223	434	399
Quantitative Analysis	**Observation**	Orientation is ambient; perspectives can be moved at will and without restrictions	Orientation is expressive; the characteristics of the mouse and the directions of the cursor is to some extent a simulation of the pen's functions, but interactive processes cannot be recorded effectively by think-aloud	Orientation is not expressive; through following links, experimenter can browse by pressing the anchor on the source node to reach the destination node.
	Interviews	Concrete models are most helpful in thinking	Cannot immediately change to the previously-seen angle; interactive mechanism is sometimes interfering.	Default paths are sometimes restrictions, and not necessarily the angle or information required by the experimenter, creating excessive restrictions.
Recommendation		Yes	Can be retained with modifications	Not Applicable

Table 1. Quantitative & Qualitative Analysis.

Quantitative Analysis

From the table, we can see that the highest number of verbal data points came from NE. Our quantitative analysis starts from the sub-system STM (short-term memory) vs. Non-STM; we can see that, in TMPA, STM verbal reports exceeded non-STM reports, and we can see that in VA in concrete models, as movement is fast and perspectives can be changed at will, the use of STM exceeds that of Non-STM, meaning that actual models can strengthen the use of STM, quickly deciding on solutions, Through functions and form, the use of actual models can create more functioning thinking, which means that think-aloud is more exploratory in TM functions. In VI (visual) vs. NVI, think-aloud can express NVI in TM as there is less interference, and the experimenter can

focus more on NVI issues.

In CMPA, the amount of data in STM exceeded that of non-STM; through the computer, we are somewhat unable to judge whether the height is the same as the length, whether the length is the same as the width, and can only judge that it is a tetragon without being able to judge whether it is a rectangle or a square. Therefore, the experimenter needed to attempt to use those recently obtained information to seek a path, and to seek an appropriate doorway. In terms of functions and form, as efforts are mostly on judging possible sizes for the model, so attention is paid on form, and this deficiency in the lack of data in terms of functionalities is required by think-aloud VA. In VI and NVI information, CM excels in presenting VI as a result of its characteristics, however, although think-aloud can easily express the experimenter's inner thinking network, interference and restrictions from operations means that the volume of data presented is less than TMPA.

For NEPA, in the volume of data for STM and Non-STM, the multi-dimensional interfaces of the Internet reduces the utilization of short term memory; for functionalities and form, investigations into functionalities are reduced, and VI and NVI information appears lacking.

Conclusion

Through inspections of the three environments and evaluations of sight and words, the Research shows that in TM, think-aloud research methods are undoubtedly applicable; for CM, the research methodologies can be used, but needs to overcome association orientation issues in operations, including the reachability of space and sight. Under a Network Environment, think-aloud is not applicable, as figurative browsing is the most effective method of browsing in a network environment, but when the network structure is too complex, a figurative browsing method increases the operating load of the user. A solution needs to be found for the user to, based on its own requirements, freely read knowledge snapshots contained inside a database, establishing individual knowledge frameworks (space structures); however, how to utilize the advantages and special characteristics of the network is a potential issue in the design process.

This Research's biggest potential difficulty is that, to have a feasible and effective CMPA and NEPA after modifications, enough representative analysis samples are required; however, there are actual issues in execution, including laboratory equipment, technical support, and the choice of qualified experimenters, etc.; preliminary results may need to be repeatedly verified and modified; therefore, the above design of research methods and methodologies need to be modified and amended according to actual circumstances. That said, through the above steps, we can still obtain staged results. Web pages built under the special characteristics and principles of the Internet has controls in the choice of paths in place that has restricted the use of the experimenter; although restrictive, it can proximate recognitions between users and designers in a NE; this Research, under the principles set forth by expert discussions and recommendations, can still be seen as valid samples.

This Research results provide appropriate and complete research methods for current computer media that are developing across fields and across subjects, not only covering development of CM or related research and development areas, but also for media research in general. Applications of methodologies investigated in this Research can push the fields of design research from a generation of traditional computer-aided resign towards a new generation based on computer media and virtual design network environment.

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